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<b>(21) International Application Number:</b> PCT/CA93/00195 <b>(22) International Filing Date:</b> 6 May 1993 (06.05.93)  <b>(30) Priority data:</b> 07/880,436 8 May 1992 (08.05.92) US 07/996,547 24 December 1992 (24.12.92) US 08/052,702 30 April 1993 (30.04.93) US  <b>(71) Applicant (for all designated States except US):</b> WESTAIM TECHNOLOGIES INC. [CA/CA]; Box #1000, Fort Saskatchewan, Alberta T8L 3W4 (CA).  <b>(72) Inventors; and</b> <b>(75) Inventors/Applicants (for US only) :</b> WU, Xingwei [CN/CA]; 14504 - 37 Street, Edmonton, Alberta T5Y 0N3 (CA). STILES, James, Alexander, Robert [CA/CA]; 12719 - 39 Avenue, Edmonton, Alberta T6J 0N3 (CA). FOO, Ken, Kok [MY/CA]; #10, 10032 - 113 Street, Edmonton, Alberta T5K 1N8 (CA). BAILEY, Phillip [GB/CA]; #102, 10011 - 89 Avenue, Edmonton, Alberta T6E 2S7 (CA).		<b>(74) Agent:</b> OGILVIE AND COMPANY; #1400 Metropolitan Place, 10303 Jasper Avenue, Edmonton, Alberta T5J 3N6 (CA).  <b>(81) Designated States:</b> AT, AU, BB, BG, BR, CA, CH, CZ, DE, DK, ES, FI, GB, HU, JP, KP, KR, LK, LU, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SK, UA, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i>
<b>(54) Title:</b> ELECTROLUMINESCENT LAMINATE WITH THICK FILM DIELECTRIC  <b>(57) Abstract</b>  An improved dielectric layer of an electroluminescent laminate, and method of preparation are provided. The dielectric layer is formed as a thick layer from a ceramic material to provide: a dielectric strength greater than about $1.0 \times 10^6$ V/m; a dielectric constant such that the ratio of the dielectric constant of the dielectric material to that of the phosphor layer is greater than about 50:1; a thickness such that the ratio of the thickness of the dielectric layer to that of the phosphor layer is in the range of about 20:1 to 500:1; and a surface adjacent the phosphor layer which is compatible with the phosphor layer and sufficiently smooth that the phosphor layer illuminates generally uniformly at a given excitation voltage. The invention also provides for electrical connection of an electroluminescent laminate to voltage driving circuitry with through hole technology. The invention also extends to laser scribing the transparent conductor lines of an electroluminescent laminate.		

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1           **ELECTROLUMINESCENT LAMINATE WITH THICK FILM DIELECTRIC**  
2                           **FIELD OF THE INVENTION**

3           This invention relates to electroluminescent  
4 laminates and methods of manufacturing same. The invention  
5 also relates to electroluminescent display panels providing  
6 for electrical connection from the electroluminescent  
7 laminate to voltage driving circuitry. The invention  
8 further relates to laser scribing a pattern in a planar  
9 laminate such as the address lines of the transparent  
10 electrode of an electroluminescent laminate.

11                           **BACKGROUND OF THE INVENTION**

12           Electroluminescence (EL) is the emission of light  
13 from a phosphor due to the application of an electric field.  
14 Electroluminescent devices have utility as lamps and  
15 displays. Currently, electroluminescent devices are used in  
16 flat panel display systems, involving either pre-defined  
17 character shapes or individually addressable pixels in a  
18 rectangular matrix.

19           Pioneering work in electroluminescence was done at  
20 GTE Sylvania. An AC voltage was applied to powder or  
21 dispersion type EL devices in which a light emitting  
22 phosphor powder was imbedded in an organic binder deposited  
23 on a glass substrate and covered with a transparent  
24 electrode. These powder or dispersion type EL devices are  
25 generally characterized by low brightness and other problems  
26 which have prevented widespread use.

27           Thin film electroluminescent (TFEL) devices were  
28 developed in the 1950's. The basic structure of an AC  
29 thin layer EL laminate is well known, see for example  
30 Tornqvist, R.O. "Thin-Film Electroluminescent Displays",  
31 Society for Information Display, 1989, International  
32 Symposium Seminar Lecture Notes, and U.S. Patent  
33 4,857,802 to Fuyama et al. A phosphor layer is sandwiched  
34 between a pair of electrodes and separated from the  
35 electrodes by respective insulating/dielectric

1 layers. Most commonly, the phosphor material is ZnS  
2 with Mn included as an activator (dopant). The ZnS:Mn  
3 TFEL is yellow emitting. Other colour phosphors have  
4 been developed.

5 The layers of conventional TFEL laminates are  
6 deposited on a substrate, usually glass. Deposition of  
7 the layers is done sequentially by known thin film  
8 techniques, for example electron beam (EB) vacuum  
9 evaporation or sputtering and, more recently, by atomic  
10 layer epitaxy (ALE). The thickness of the entire TFEL  
11 laminate is only in the order of one or two microns.

12 To separate and electrically insulate the  
13 phosphor layer from the electrodes, various  
14 insulating/dielectric materials are known and used, as  
15 discussed in more detail hereinafter.

16 Each of the two electrodes differ, depending  
17 on whether it is at the "rear" or the "front" (viewing)  
18 side of the device. A reflective metal, such as  
19 aluminum is typically used for the rear electrode. A  
20 relatively thin optically transmissive layer of indium  
21 tin oxide (ITO) is typically employed as the front  
22 electrode. In lamp applications, both electrodes take  
23 the form of continuous layers, thereby subjecting the  
24 entire phosphor layer between the electrodes to the  
25 electric field. In a typical display application, the  
26 front and rear electrodes are suitably patterned with  
27 electrically conductive address lines defining row and  
28 column electrodes. Pixels are defined where the row and  
29 column electrodes overlay. Various electronic display  
30 drivers are well known which address individual pixels  
31 by energizing one row electrode and one column electrode  
32 at a time.

33 While simple in concept, the development of  
34 thin film electroluminescent devices has met with many  
35 practical difficulties. A first difficulty arises from  
36 the fact that the devices are formed from individual  
37 laminate layers deposited by thin film techniques which

1 are time consuming and costly techniques. A very small  
2 defect in any particular layer can cause a failure.  
3 Secondly, these thin-film devices are typically operated  
4 at relatively high voltages, eg. 300 - 450 volts peak to  
5 peak. In fact, these voltages are such that the  
6 phosphor layer is operated beyond its dielectric  
7 breakdown voltage, causing it to conduct. The thin-film  
8 dielectric layers on either side of the phosphor layer  
9 are required to limit or prevent conduction between the  
10 electrodes. The application of the large electric  
11 fields can cause electrical breakdown between the  
12 electrodes, resulting in failure of the device.

13 The present invention is particularly directed  
14 to the insulating/dielectric layers of  
15 electroluminescent devices and the prevention of  
16 electrical discharges across the phosphor layer. A  
17 requirement for successful operation of an  
18 electroluminescent device is that the electrodes  
19 (address lines) be electrically isolated from the  
20 phosphor layer. This function is provided by the  
21 insulating/dielectric layers. Typically,  
22 insulating/dielectric layers are provided on either side  
23 of the phosphor layer and are constructed from alumina,  
24 yttria, silica, silicon nitride or other dielectric  
25 materials. During operation of the device, electrons  
26 from the interface between the insulating layer and the  
27 phosphor layer are accelerated by the electric field as  
28 they pass through the phosphor layer, and collide with  
29 the dopant atoms in the phosphor layer, emitting light  
30 as a result of the collision process. In a conventional  
31 TFEL device, to ensure that the electric field strength  
32 across the phosphor is sufficiently high, the thickness  
33 of the dielectric layers is usually kept less than or  
34 comparable to that of the phosphor layer. If the  
35 dielectric layers are too thick a large portion of the  
36 voltage applied between the address lines is across the  
37 dielectric layers rather than across the phosphor layer.

1                   It is important that the dielectric material  
2                   be compatible with the phosphor layer. By "compatible",  
3                   as used in this specification and in the claims, is  
4                   meant that, firstly, it provides a good injectivity  
5                   interface, i.e. a source of "hot" electrons at the  
6                   phosphor interface which can be promoted or tunnelled  
7                   into the phosphor conduction band to initiate conduction  
8                   and light emission in the phosphor layer on application  
9                   of an electric field. Secondly, within the meaning of  
10                  compatible, the dielectric material must be chemically  
11                  stable so that it does not react with adjacent layers,  
12                  that is the phosphor or the electrodes.

13                 In a typical TFEL, in order to achieve  
14                 sufficient luminosity, the applied voltage is very near  
15                 that at which electrical breakdown of the dielectric  
16                 occurs. Thus, the manufacturing control over the  
17                 thickness and quality of the dielectric and phosphor  
18                 layers must be stringently controlled to prevent  
19                 electrical breakdown. This requirement in turn makes it  
20                 difficult to achieve high manufacturing yields.

21                 A typical TFEL structure is constructed from  
22                 the front (viewing) side to the rear. The thin layers  
23                 are sequentially deposited on a suitable substrate.  
24                 Glass substrates are utilized to provide transparency.  
25                 The transparent, front electrode (ITO address lines) is  
26                 deposited on the glass substrate by sputtering to a  
27                 thickness of about 0.2 microns. The subsequent  
28                 dielectric - phosphor - dielectric layers are then  
29                 usually deposited by sputtering or evaporation. The  
30                 thickness of the phosphor layer is typically about 0.5  
31                 microns. The dielectric layers are typically about 0.4  
32                 microns thick. The phosphor layer is usually annealed  
33                 after deposition at about 450°C to improve efficiency.  
34                 The rear electrode is then added, typically in the form  
35                 of aluminum address lines with a thickness of 0.1  
36                 microns. The finished TFEL laminate is encapsulated in  
37                 order to protect it from external humidity. Epoxy

1 laminated cover glass or silicon oil encapsulation are  
2 used. In that the initial substrate used for deposition  
3 is typically glass, the materials and deposition  
4 techniques employed in TFEL laminate construction cannot  
5 demand high temperature processing.

6 The high electric field strength used to  
7 operate a TFEL device puts heavy requirements on the  
8 dielectric layers. High dielectric strengths are  
9 required to avoid electrical breakdown. Dielectrics  
10 with high dielectric constants are preferred in order to  
11 provide luminosity at the lowest possible driving  
12 voltage. However, efforts to utilize high dielectric  
13 constant materials have not provided satisfactory  
14 results.

15 To lower the driving voltage of TFEL elements  
16 insulating layers have been constructed from higher  
17 dielectric constant materials, for instance  $\text{SrTiO}_3$ ,  
18  $\text{PbTiO}_3$ , and  $\text{BaTa}_2\text{O}_7$ , as reported in U.S. Patent 4,857,802  
19 issued to Fuyama et al. However, these materials have  
20 not performed well, exhibiting low dielectric breakdown  
21 strengths. In U.S. Patent 4,857,802, a dielectric layer  
22 is formed from a perovskite crystal structure by  
23 controlled thin film deposition techniques to achieve an  
24 increased (111) plane orientation. The patent reports  
25 higher dielectric strengths (above about  $8.0 \times 10^5$  -  
26 about  $1.0 \times 10^6$  V/cm) with a dielectric layer having a  
27 thickness of about 0.5 microns using  $\text{SrTiO}_3$ ,  $\text{PbTiO}_3$ , and  
28  $\text{BaTiO}_3$ , all of which have high dielectric constants and  
29 a perovskite crystal structure. This device still has  
30 the disadvantage of requiring complex and difficult to  
31 control thin film deposition techniques for the  
32 dielectric layer.

33 Efforts have also been made to develop TFEL  
34 devices using a thick ceramic insulator layer and a thin  
35 film electroluminescent layer, see Miyata, T. et al.,  
36 SID 91 Digest, pp 70-73 and 286-289. The device is  
37 built up from a  $\text{BaTiO}_3$  ceramic sheet. The sheet is

1 formed by molding fine BaTiO<sub>3</sub> powder into disks (20 mm  
2 diameter) by conventional cold-press methods. The disks  
3 are sintered in air at 1300°C, then ground and polished  
4 into sheets with a thickness of about 0.2 mm. The  
5 emitting layer is deposited onto the sheet in a thin  
6 film using chemical vapour deposition or RF magnetron  
7 sputtering. Suitable electrode layers are then  
8 deposited by thin film techniques on either side of the  
9 structure. While this device exhibits certain desirable  
10 characteristics, it is not feasible to manufacture a  
11 commercial TFEL device from a solid ceramic sheet.  
12 Grinding and polishing a larger ceramic sheet to a  
13 consistent thickness of 0.2 mm is not practical  
14 economically.

15 It is also known in the art to use multiple  
16 insulating/dielectric layers on each side of the  
17 phosphor layer. For instance, U.S. Patent 4,897,319 to  
18 Sun discloses a TFEL with an EL phosphor layer  
19 sandwiched between a pair of insulator stacks, in which  
20 one or both of the insulator stacks includes a first  
21 layer of silicon oxynitride (SiON) and a second thicker  
22 layer of barium tantalate (BTO). The first, SiON layer  
23 provides high resistivity while the second, BTO layer  
24 has a higher dielectric constant. Overall, the  
25 structure is stated to produce a higher luminance of the  
26 phosphor layer at conventional voltages. However, the  
27 insulating layers are deposited by RF sputtering, which  
28 has the disadvantages of thin film techniques described  
29 hereinabove.

30 There is a need for a TFEL device having  
31 higher luminosity and lower operating voltage than  
32 conventional TFEL devices, while still being feasible to  
33 construct. It is necessary to achieve this with a  
34 dielectric layer which has a dielectric strength that is  
35 above the electric field strength needed to drive the  
36 device.



1                   Fabricating electrode patterns in transparent  
2 conductor materials such as indium tin oxide often  
3 involves extensive and expensive masking,  
4 photolithographic and chemical etching processes.  
5 Lasers have been proposed for scribing such transparent  
6 conductor materials. Generally carbon dioxide, argon  
7 and YAG lasers are used. Such lasers produce light in  
8 the visible and infrared ranges of the electromagnetic  
9 spectrum (generally greater than 400 nm). However,  
10 there are problems in using such long wavelength light  
11 to scribe electrode patterns, particularly when the  
12 transparent conductor material is deposited on another  
13 transparent layer. In conventional TFEL displays, the  
14 transparent electrode material, typically indium tin  
15 oxide (ITO), is deposited on the transparent display  
16 glass (substrate) prior to depositing the remaining  
17 layers of the EL laminate. In an insulator or a  
18 semiconducting material, light with a wavelength longer  
19 than that corresponding to the energy of the electronic  
20 band gap in the material is not strongly absorbed. For  
21 optically transparent materials, the wavelength  
22 corresponding to the band gap is shorter than that for  
23 visible light. Therefore, transparent electrode  
24 materials show poor absorption of laser light due to  
25 both the long wavelength of the light and the thinness  
26 of the layer, making it difficult to utilize laser  
27 energy to directly ablate the electrode address lines.

28                   U.S. Patents 4,292,092, to Hanak and  
29 4,667,058, to Catalano et al., disclose processes to  
30 pattern a transparent electrode pattern deposited on  
31 another transparent layer in a solar battery. The  
32 patents teach patterning the electrode using a pulsed  
33 YAG laser, which produces light with a wavelength too  
34 long to be significantly absorbed in any of the  
35 transparent layers. To compensate for the low  
36 absorption, a laser with high peak power is used to  
37 thermally vaporize the transparent electrode. A

1 neodymium YAG laser is operated at 4-5 W with a pulse  
2 rate of 36 KHz at a scanning rate of 20 cm/sec. The  
3 examples of the patent disclose scribing an ITO layer  
4 deposited on glass in this manner. However, the scribed  
5 lines are described as having incompletely removed the  
6 ITO and, in places, as having melted the glass to a  
7 depth of a few hundred angstroms. The residual ITO must  
8 thereafter be removed by a subsequent etching step.

9 Other approaches to forming electrode patterns  
10 in transparent electrode materials involve using an  
11 excimer laser, which produces light of shorter  
12 wavelength, in the ultraviolet region of the  
13 electromagnetic spectrum. At this wavelength, the laser  
14 energy can be absorbed by the transparent electrode  
15 material. Lasers of this nature are suggested to form  
16 conductive patterns for liquid crystal displays (U.S.  
17 Patents 4,980,366, to Imatou et al and 4,927,493, to  
18 Yamazaki et al.), photovoltaic batteries (U.S. Patents  
19 4,783,421, to Carlson et al. and 4,854,974, to Yamazaki  
20 et al.) imaging sensors (U.S. Patent 5,043,567, to  
21 Sakama et al.), and integrated circuits (U.S. Patent  
22 5,109,149, to Leung). WO 90/0970, published August 23,  
23 1990, to Autodisplay A/S, discloses a process for  
24 scribing an electrode dot matrix pattern in a  
25 transparent conductor on a transparent substrate with an  
26 excimer laser.

27 While excimer lasers produce light which has  
28 a wavelength short enough to be absorbed by the  
29 transparent electrode such that the electrode may be  
30 patterned by direct ablation, such lasers are relatively  
31 expensive and the scribing process must be carefully  
32 controlled to avoid melting or ablating the underlying  
33 display glass. Furthermore, such processes may lead to  
34 excessive or incomplete ablation of the transparent  
35 electrode material. For instance in WO 90/0970 there is  
36 an indication that, in the event of partial removal of

1 the material to be ablated, remaining portions may be  
2 removed by chemicals or plasma etching.

3 Another problem encountered in scribing  
4 transparent electrode materials on a transparent  
5 substrate is addressed in U.S. patent 4,937,129, to  
6 Yamazaki. To avoid diffusion or cross contamination  
7 between the layers, diffusion barrier layers are  
8 provided at the interface.

9 Other patents have taught surface treatments  
10 of the transparent electrode material to enhance  
11 absorption of the laser light. For instance, U.S.  
12 Patent 4,909,895, to Cusano, teaches oxidizing the  
13 metallic film surface to make it less reflective of the  
14 laser light. U.S. Patent 4,568,409, to Caplan, teaches  
15 coating the transparent layer to be ablated with a dye  
16 to selectively absorb laser light where ablation is  
17 desired.

18 Control circuitry to drive an EL display has  
19 been developed. Basically, the circuitry converts  
20 serial video data into parallel data to apply a voltage  
21 to the rows and columns of the display. State of the  
22 art row and column driver components (chips) are  
23 available.

24 Asymmetric and symmetric drive techniques are  
25 used with EL displays. In an asymmetric drive method,  
26 the EL panel is provided with drive pulses by applying  
27 a negative subthreshold voltage to one row at a time.  
28 During each row scan time, a positive voltage pulse is  
29 applied to the selected columns (i.e. those that should  
30 illuminate) and zero voltage is applied to the  
31 nonselected columns (i.e. those that should not  
32 illuminate). At the intersection of selected columns  
33 and rows, a voltage equal to the sum of the subthreshold  
34 row voltage and the positive pulse voltage on the column  
35 is applied across the pixel, causing light emission.  
36 After all rows of the panel have been addressed, a

1 positive polarity refresh pulse is applied to all of the  
2 rows simultaneously, and all columns are held at 0 V.

3 In a symmetrical drive scheme, the refresh  
4 pulse is eliminated. Instead, a similar set of drive  
5 pulses that are of the opposite polarity are applied to  
6 the panel. To maintain the panel in operation, the rows  
7 are scanned with pulses of alternating polarity on even  
8 and odd frames. The alternating polarity produces a net  
9 zero charge on all display pixels.

10 State of the art high voltage driver  
11 components (chips) are available for both asymmetric and  
12 symmetric drive techniques.

13 Alternate driving circuits and components for  
14 EL displays are known or are in development, see for  
15 example K. Shoji et al, Bidirectional Push-Pull  
16 Symmetric Driving Method of TFEL Display, Springer  
17 Proceedings in Physics, Vol. 38, 1989, 324; and Sutton  
18 S. et al, Recent Developments and Trends in Thin-Film  
19 Electroluminescent Display Drivers, Springer Proceedings  
20 in Physics, Vol. 38, 1989, 318; and Bolger et al, A  
21 Second Generation Chip Set for Driving EL Panels, SID,  
22 1985, 229.

23 The above driving schemes are termed  
24 multiplexed (passive) matrix addressing schemes.  
25 Theoretically, other types of driving schemes, such as  
26 active matrix addressing schemes, could be used with EL  
27 displays. However, these are not yet developed. Such  
28 alternate driving schemes should be considered to be  
29 within the meaning of the phrase voltage driving  
30 circuitry as used in this application.

31 In conventional EL displays, one method to  
32 connect the column and row address lines to the driver  
33 circuit is to compress a polymeric strip containing very  
34 many closely spaced metal sheets between rows of  
35 contacts connected to the display address lines and rows  
36 of contacts connected to the driver components of the  
37 driver circuit, which is constructed on a separate

1 circuit board (see U.S. Patent 4,508,990, to Essinger).  
2 The polymeric strip is a layered elastomeric element  
3 (LEE), known by such tradenames as STAX and ZEBRA. The  
4 LEE is composed of alternating layers of conductive and  
5 non-conductive elastomeric materials. The polymeric  
6 strip avoids the need to laboriously connect hundreds of  
7 individual wires using solder or welded connections to  
8 the contacts. However, this interconnection technology  
9 is unreliable, and does not function well at high  
10 temperatures, which can cause the polymeric material to  
11 creep.

12 Another method that is commonly used to  
13 connect column and row address lines to the driver  
14 circuit for liquid crystal displays (LCDs) is being  
15 considered for electroluminescent displays, namely chip-  
16 on-glass (COG) technology. The driver components  
17 (chips) to which the address lines must be connected are  
18 mounted around the periphery of the display. In the  
19 case of LCDs, the address lines, which are evaporated on  
20 the rear side of the display glass, are extended from  
21 the active region of the display so that they end in  
22 contact pads that are arranged in a pattern so that the  
23 chips can be wire bonded thereto. Wire bonding entails  
24 mounting the chips on the display glass and then  
25 individually welding fine gold wires to the output pads  
26 on the chip and to the corresponding contact pads on the  
27 address lines.

28 The advantage of COG technology is that the  
29 number of contacts between the display glass and the  
30 driver circuit are substantially reduced, since by far  
31 the largest number of contacts are between the driver  
32 chips and the address lines. There are typically only  
33 about 20 to 30 connections between the driver chips and  
34 the rest of the driving circuit as opposed to up to 2000  
35 connections to the address lines.

36 One major disadvantage of the COG technology  
37 is that difficulty is experienced in wire bonding the

1 driver chips to connect them to the thin film pads on  
2 the address lines, resulting in poor manufacturing  
3 yields. Another disadvantage is that space is required  
4 around the perimeter of the display to mount the driver  
5 chips, thus increasing the bulkiness of the displays and  
6 eliminating any possibility of joining several display  
7 modules in an array to form a larger display.

8 Through hole technology for direct circuit  
9 connections is widely known in the semiconductor art  
10 (see for example U.S Patent 3,641,390, Nakamura). U.S.  
11 Patent 4,710,395, to Young et al, describes methods and  
12 apparatus for through hole substrate printing with  
13 regulated vacuum. However, through hole printing has  
14 not, to the inventors' knowledge, been successfully  
15 applied to EL displays.

16 U.S. Patent 3,504,214 to Lake et al describes  
17 a segmented storage type of EL device in which pixels  
18 are turned on with light to make a photoconductive layer  
19 next to the phosphor layer become electrically  
20 conductive. Complex through hole conductors are  
21 described. The patent indicates that ordinary through  
22 hole connections do not work with high resolution TFEL  
23 displays because the conductive material might react  
24 with the phosphor, thereby degrading the performance of  
25 the display.

#### 26 SUMMARY OF THE INVENTION

27 Layers of a electroluminescent laminate have  
28 different dielectric constants. A potential difference  
29 across the layers of the laminate is divided  
30 proportionately across each layer in accordance with the  
31 thickness of each layer, and inversely with the relative  
32 dielectric constants of the materials. For instance, if  
33 one layer has a thickness and a dielectric constant that  
34 are both twice that of the other layer, the voltage  
35 would be divided equally between the two layers. The  
36 present invention uses this property to combine a thick

1 dielectric layer having a high dielectric constant with  
2 a thinner phosphor layer having a substantially lower  
3 dielectric constant. In this way, prior to the  
4 initiation of conduction through the phosphor layer, the  
5 voltage across a pixel can be largely across the  
6 phosphor layer, provided the dielectric layer has a  
7 sufficiently high dielectric constant. The

8 present invention provides an EL laminate, and method of  
9 manufacturing same, with a novel and improved dielectric  
10 layer. The dielectric layer is formed as a thick layer  
11 from a ceramic material to provide:

12 - a dielectric strength greater than about 1.0  
13  $\times 10^6$  V/m;

14 - a dielectric constant such that the ratio of  
15 the dielectric constant of dielectric material ( $k_2$ ) to  
16 that of the phosphor layer ( $k_1$ ) is greater than about  
17 50:1 (preferably greater than 100:1);

18 - a thickness such that the ratio of the  
19 thickness of the dielectric layer ( $d_2$ ) to that of the  
20 phosphor layer ( $d_1$ ) is in the range of about 20:1 to  
21 500:1 (preferably 40:1 to 300:1); and

22 - a surface adjacent the phosphor layer which  
23 is compatible with the phosphor layer and sufficiently  
24 smooth that the phosphor layer illuminates generally  
25 uniformly at a given excitation voltage.

26 The laminate including the dielectric layer of  
27 the present invention is most preferably one in which  
28 the phosphor layer is a thin film layer. A typical thin  
29 film phosphor layer is formed from ZnS:Mn with a  
30 thickness of about 0.2 to 2.0 microns, typically about  
31 0.5 microns. The material ZnS:Mn has a dielectric  
32 constant of about 5 to 10. From theoretical  
33 calculations, based on this most preferred phosphor  
34 layer (see guidelines set out hereinabove), the  
35 dielectric layer of the present invention preferably has  
36 a dielectric constant greater than about 500, and most  
37 preferably greater than about 1000, and a thickness in

1 the range of about 10 - 300 microns and preferably in  
2 the range of 20 - 150 microns. To achieve the high  
3 dielectric constant, ferroelectric materials are  
4 preferred, most preferably those having a perovskite  
5 crystal structure. Exemplary materials include  $\text{PbNbO}_3$ ,  
6  $\text{BaTiO}_3$ ,  $\text{SrTiO}_3$ , and  $\text{PbTiO}_3$ .

7 The dielectric layer of this invention is  
8 formed in a laminate which is constructed from the rear  
9 to the front. The rear electrode is thus deposited on  
10 a substrate, most preferably a ceramic such as alumina,  
11 which can withstand higher temperatures in manufacture  
12 than can glass substrates (used in front to rear TFEL  
13 construction in order to provide front transparency).  
14 The dielectric layer of the invention is then deposited,  
15 by thick film techniques, on the rear electrode. It is  
16 then sintered at a high temperature, but one which can  
17 be withstood by the substrate and rear electrode. The  
18 use of thick film techniques and high temperature  
19 sintering is important to the overall properties of the  
20 dielectric layer because a dense layer with a high  
21 degree of crystallinity is achieved, which improves the  
22 overall dielectric constant and dielectric strength of  
23 the layer.

24 In practice, the inventors have found that it  
25 is difficult to produce the desired surface of the  
26 dielectric adjacent the phosphor layer (i.e. compatible  
27 and smooth) with the presently available ceramic  
28 materials. Thus, in a preferred embodiment of the  
29 invention, the dielectric layer is formed as two layers,  
30 a first dielectric layer formed on the rear electrode  
31 and having the preferred high dielectric strength and  
32 dielectric constant values set out hereinabove, and a  
33 second dielectric layer which provides the surface  
34 adjacent the phosphor layer as set out above.

35 In a preferred embodiment of the invention,  
36 the first dielectric layer is deposited by thick film  
37 techniques (preferably screen printing) followed by high



1 temperature sintering (preferably less than the melting  
2 point of all lower layers, typically less than 1000°C).  
3 Pastes containing ferroelectric ceramics, preferably  
4 having perovskite crystal structures, as set above are  
5 preferred materials, provided the paste formulation  
6 permits sintering at the high sintering temperature.  
7 The second dielectric layer is preferably deposited by  
8 sol gel techniques, followed by high temperature  
9 sintering, to provide a smooth surface. The material  
10 used in the second layer preferably provides a high  
11 dielectric constant (preferably greater than 20, more  
12 preferably greater than 100) and a thickness greater  
13 than 2 microns (preferably 2 - 10 microns).  
14 Ferroelectric ceramics with perovskite crystal  
15 structures are most preferred.

16 The invention has been demonstrated with a  
17 first dielectric layer screen printed from lead niobate  
18 with a thickness of 30 microns, and a second dielectric  
19 layer spin deposited as a sol from lead zirconate  
20 titanate with a thickness of 2 - 3 microns. The sol gel  
21 layer has also been demonstrated by dipping to form  
22 several layers with a total thickness of 6-10 microns.  
23 Lead lanthanum zirconate titanate is also demonstrated  
24 as a sol gel layer.

25 The use of a two layer dielectric, while not  
26 essential, has its advantages. While the first  
27 dielectric layer is formed as a thick layer with the  
28 needed high dielectric strength and high dielectric  
29 constant, the second layer is not so limited. Provided  
30 the second layer has the desired compatible and smooth  
31 surface, it can be formed as a thinner layer from  
32 different materials than used in the first layer. Much  
33 research has been done on altering the properties of the  
34 dielectric - phosphor interface of EL laminates, for  
35 instance to improve chemical stability or injectivity.  
36 Materials or deposition techniques including these  
37 improvements can be used with the first and/or second

1 dielectric layers of this invention, for instance in the  
2 choice of materials or deposition techniques used in the  
3 first or second layer, by altering the surface of the  
4 second layer, or by applying a further thin film layer  
5 of a third material above the first or second layer.

6 Laminates made in accordance with the present  
7 invention have been demonstrated to exhibit good  
8 luminosity without breakdown at low operating voltages.  
9 The preferred thick film and sol gel deposition  
10 techniques for the dielectric layer(s) are generally  
11 simple and inexpensive techniques compared to the thin  
12 film techniques described hereinabove. Another  
13 advantage of the dielectric layer(s) of this invention  
14 is that laminates incorporating the layer(s) do not  
15 require a further dielectric layer between the phosphor  
16 layer and the second electrode, although such a further  
17 dielectric layer may be included if desired.

18 Thus, in one broad aspect, the invention  
19 provides a dielectric layer in an electroluminescent  
20 laminate of the type including a phosphor layer  
21 sandwiched between a front and a rear electrode, the  
22 rear electrode being formed on a substrate and the  
23 phosphor layer being separated from the rear electrode  
24 by a dielectric layer. The dielectric layer comprises  
25 a planar layer formed from a ceramic material providing  
26 a dielectric strength greater than about  $1.0 \times 10^6$  V/m  
27 and a dielectric constant such that the ratio of  $k_2/k_1$  is  
28 greater than about 50:1, the dielectric layer having a  
29 thickness such that the ratio of  $d_2:d_1$  is in the range of  
30 about 20:1 to 500:1, and the dielectric layer having a  
31 surface adjacent the phosphor layer which is compatible  
32 with the phosphor layer and sufficiently smooth that the  
33 phosphor layer illuminates generally uniformly at a  
34 given excitation voltage.

35 The invention also broadly extends to a method  
36 of forming a dielectric layer in an electroluminescent  
37 laminate of the type including a phosphor layer

1 sandwiched between a front and a rear electrode, the  
2 rear electrode being formed on a substrate and the  
3 phosphor layer being separated from the rear electrode  
4 by a dielectric layer. The method comprises depositing  
5 on the rear electrode, by thick film techniques followed  
6 by sintering, a ceramic material having a dielectric  
7 constant such that the ratio of  $k_2/k_1$  is greater than  
8 about 50:1, to form a dielectric layer having a  
9 dielectric strength greater than about  $1.0 \times 10^6$  V/m and  
10 a thickness such that the ratio of  $d_2/d_1$  is in the range  
11 of about 20:1 to 500:1, the dielectric layer forming a  
12 surface adjacent the phosphor layer which is compatible  
13 with the phosphor layer and sufficiently smooth that the  
14 phosphor layer illuminates generally uniformly at a  
15 given excitation voltage.

16 This invention also broadly provides a process  
17 for laser scribing a pattern in a planar laminate having  
18 at least one overlying layer and at least one underlying  
19 layer, comprising:

20 applying a focused laser beam on the overlying  
21 layer side of the laminate, said laser beam having a  
22 wavelength which is substantially unabsorbed by the  
23 overlying layer but which is absorbed by the underlying  
24 layer, such that at least a portion of the underlying  
25 layer is directly ablated and the overlying layer is  
26 indirectly ablated throughout its thickness.

27 In the context of an EL laminate, the  
28 overlying layers are the transparent conductive material  
29 and the phosphor, the underlying layers are one or more  
30 dielectric layers and the pattern is an electrode  
31 pattern of parallel spaced address lines.

32 Throughout the specification and the claims,  
33 the following definitions apply:

34 Absorption occurs in a material when a quantum  
35 of radiant energy coincides with an allowed transition  
36 within the material to a higher energy state, for

1 example by promotion of electrons across the band gap  
2 for that material.

3 Direct ablation of a material by a laser beam  
4 occurs when the dominant cause of ablation is  
5 decomposition and/or due to absorption of the radiant  
6 energy of the laser beam by the material.

7 Indirect ablation of a material by a laser  
8 beam occurs when the dominant cause of ablation is  
9 vaporization due to heat generated in, and transported  
10 from, an adjacent material which absorbs the radiant  
11 energy of the laser beam.

12 The invention also extends to an  
13 electroluminescent display panel providing for  
14 electrical connection from a planar electroluminescent  
15 laminate to the output of one or more voltage driving  
16 components of a driver circuit using through hole  
17 connectors. The display panel includes:

18 - an electroluminescent laminate formed on a  
19 rear substrate and having front and rear sets of  
20 intersecting address lines such as is known in the art;

21 - a plurality of through holes formed in the  
22 substrate adjacent the ends of the address lines; and

23 - means forming a conductive path through each  
24 of the through holes in the substrate to the ends of  
25 each of the address lines to provide for electrical  
26 connection of each address line to a voltage driving  
27 component of the driving circuit.

28 Preferably, the electroluminescent laminate of  
29 the display panel includes the thick film dielectric  
30 layer of the present invention. This dielectric layer  
31 enables the laminate to be constructed from the rear  
32 substrate toward the front viewing side, which in turn  
33 enables the through hole connectors and thick film  
34 circuit patterns for connection to the voltage driving  
35 components and address lines to be formed by  
36 interleaving the circuit fabrication steps with the  
37 fabrication steps for the electroluminescent laminate.

1 Such steps could not easily be accomplished in the  
2 construction of a conventional electroluminescent  
3 laminate since the layers are deposited on the front  
4 display glass which will not withstand temperatures to  
5 fire thick film conductive pastes.

6 In accordance with the present invention, the  
7 voltage driving components or the entire driving circuit  
8 may be formed on the rear (reverse) side of the rear  
9 substrate. The use of through hole connectors provides  
10 for more direct, highly reliable interconnections  
11 between the address lines and the driving circuit. A  
12 non-active perimeter around the display panel, as is  
13 needed in the prior art, is not needed. This  
14 facilitates the assembly of large displays from  
15 individual display panels without dark boundaries  
16 between the modules.

#### 17 DESCRIPTION OF THE DRAWINGS

18 Figure 1 is a schematic, cross sectional view  
19 of the laminate structure including a two layer  
20 dielectric of the present invention; and

21 Figure 2 is a top view of the laminate  
22 structure of Figure 1.

23 Figure 3 is a schematic cross sectional view  
24 of the laminate structure along a column electrode  
25 showing the preferred embodiment of connecting the row  
26 and column electrode address lines to the voltage  
27 driving components of the voltage driving circuit;

28 Figure 4 is a top view of the rear substrate  
29 with the preferred pattern of through holes for  
30 electrical connection of the address lines to the  
31 voltage driving components of the driver circuit;

32 Figure 5 is a top view of a preferred driver  
33 circuit pattern printed on the rear side of the rear  
34 substrate;

1                   Figure 6 is a top view of the row electrodes  
2 and column pads printed on the front side of the rear  
3 substrate;

4                   Figure 7 is a top view of the circuit pad  
5 reinforcement pattern preferably printed over the driver  
6 circuit pattern of Figure 5;

7                   Figure 8 is a top view of the sealing glass  
8 pattern preferably printed over the driver circuit  
9 pattern and circuit pad reinforcement pattern of Figures  
10 5 and 7;

11                  Figure 9 is a top view of the column electrode  
12 line pattern; and

13                  Figure 10 is a top view of the electrical  
14 connections printed between the column lines of Figure  
15 9 and the column pads of Figure 6.

#### 16                   DESCRIPTION OF THE PREFERRED EMBODIMENTS

17                   An EL laminate 10 incorporating a two layer  
18 dielectric in accordance with the present invention is  
19 illustrated in Figures 1 and 2. The laminate 10 is  
20 built from the rear side on a substrate 12. A rear  
21 electrode layer 14 is formed on the substrate 12. As  
22 shown in the Figures, for display applications, the rear  
23 electrode 14 consists of rows of conductive address  
24 lines centered on the substrate 12 and spaced from the  
25 substrate edges. A electric contact tab 16 protrudes  
26 from the electrode 14. A first, thick dielectric layer  
27 18 is formed above the rear electrode 14, followed by a  
28 second, thinner dielectric layer 20. A phosphor layer  
29 22 is formed above the second dielectric layer 20,  
30 followed by a front, transparent electrode layer 24.  
31 The front electrode layer 24 is shown in the Figures as  
32 solid, but in actuality, for display applications, it  
33 consists of columns of address lines arranged  
34 perpendicular to the address lines of the rear electrode  
35 14. The laminate 10 is encapsulated with a transparent  
36 sealing layer 26 to prevent moisture penetration. An

1 electric contact 28 is provided to the second electrode  
2 24.

3 The EL laminate 10 is operated by connecting  
4 an AC power source to the electrode contacts 16, 28. An  
5 EL laminate in accordance with the invention has utility  
6 as lamps or displays, although it will most frequently  
7 find application in displays.

8 It will be understood by persons skilled in  
9 the art that further intervening layers can be included  
10 in the laminate 10 without departing from the present  
11 invention.

12 A method of constructing a double dielectric  
13 layer in an EL laminate, in accordance with the  
14 invention, will now be described with preferred  
15 materials and process steps.

16 The laminate 10 is constructed from the rear  
17 to the front (viewing) side. The laminate 10 is formed  
18 on a suitable substrate 12. The substrate 12 is  
19 preferably a ceramic which can withstand the high  
20 sintering temperatures (typically 1000°C) used in the  
21 dielectric layer. Alumina is most preferred.

22 Deposited on the substrate 12 is the first,  
23 rear electrode 14. Many techniques and materials are  
24 known for laying down thin rows of address lines.  
25 Preferably, conductive metal address lines are screen  
26 printed from a Ag/Pt alloy paste, using an emulsion  
27 which can be washed away in the areas where the paste is  
28 to be printed. The paste is thereafter dried and fired.  
29 Alternatively, the rear electrode 14 may be formed from  
30 other noble metals such as gold, or other metals such as  
31 chromium, tungsten, molybdenum, tantalum or alloys of  
32 these metals.

33 The first dielectric layer 18 is deposited on  
34 the rear electrode by known thick film techniques. The  
35 first dielectric layer 18 is preferably formed from a  
36 ferroelectric material, most preferably one having a  
37 perovskite crystal structure, to provide a high

1 dielectric constant compared to that of the phosphor  
2 layer 22. The material will have a minimum dielectric  
3 constant of 500 over a reasonable operating temperature  
4 for the laminate, generally 20 - 100°C. More preferably,  
5 the dielectric constant of the first dielectric layer  
6 material is 1000 or greater. Exemplary materials for  
7 the first dielectric layer 18 include  $\text{PbNbO}_3$ ,  $\text{BaTiO}_3$ ,  
8  $\text{SrTiO}_3$ , and  $\text{PbTiO}_3$ ,  $\text{PbNbO}_3$  being particularly preferred.

9 As will be understood by persons skilled in  
10 this art, in choosing a ceramic material (i.e. an  
11 electrical insulating material having a melting point  
12 which is sufficiently high to allow for the preparation  
13 of the other layers of the laminate) for the first  
14 dielectric layer 18, one chooses materials known to have  
15 high dielectric constants and dielectric strengths.  
16 These are intrinsic properties of the materials,  
17 however, the values are generally given for bulk  
18 materials, which are present in a dense, highly  
19 crystalline form. The deposition techniques used can  
20 alter these properties. In respect of the dielectric  
21 constant of the material, the thick film deposition  
22 techniques, followed by high temperature sintering, will  
23 generally preserve a large particle size (in the range  
24 of about 1 micron to about 2 microns) and a high degree  
25 of crystallinity in a dense structure, so as not to  
26 significantly lower the dielectric constant from that of  
27 the starting material. Similarly, a high dielectric  
28 strength is achieved using thick film deposition  
29 techniques followed by high temperature sintering.  
30 However, the dielectric strength of the layer(s) should  
31 ultimately be measured by imposing an operating voltage  
32 across the completed laminate.

33 Thick film deposition techniques are known in  
34 the art, as set forth above. By such techniques, the  
35 dielectric material is deposited on the rear electrode  
36 layer 14 to the desired thickness with generally uniform  
37 coverage. Thick film deposition techniques are



frequently used in the manufacture of electronic circuits on ceramic substrates. Screen printing is the most preferred technique. Commercially available dielectric pastes can be used, with the recommended sintering steps set out by the paste manufacturers. Pastes should be chosen or formulated to permit sintering at a high temperature, typically about 1000°C. However, other techniques can achieve similar results. One alternate thick film technique is the use a dielectric as a "green tape", such that it can be laid down on the rear electrode 14. The green tape comprises a dielectric powder in a polymeric matrix that can be burned out during the subsequent sintering process. The tape is flexible before sintering, and can be rolled or pressed onto the electrode layer 14. One possible advantage of the green tape over the screen printed dielectric is that it may be somewhat more dense with fewer pores once it is fired. At present, green tape dielectrics are not widely available. Thick film pastes of the dielectric can also be roll coated onto the rear electrode layer 14, or applied with a doctor blade. More complex techniques such as electrostatic deposition of a dielectric powder followed by immediate sintering before the powder loses its electrostatic charge may also be used.

As indicated, the first dielectric layer 18 is preferably screen printed from a paste. Depositing in multiple layers followed by sintering at a high temperature is preferred in order to achieve low porosity, high crystallinity and minimal cracking. The sintering temperature will depend on the particular material being used, but will not exceed the temperature which the rear electrode 14 or substrate 12 can withstand. A temperature of 1000°C is typically the maximum for most electrode materials. The thickness of the first dielectric layer 18 will vary with its dielectric constant and with the dielectric constants

1 and thicknesses of the phosphor layer 22 and the second  
2 dielectric layer 20. Generally, the thickness of the  
3 first dielectric layer 18 is in the range of 10 to 300  
4 microns, preferably 20 - 150 microns, and more  
5 preferably 30 - 100 microns.

6 It will be appreciated that, in general, the  
7 criteria for establishing the thickness and dielectric  
8 constant of the dielectric layer(s) are calculated so as  
9 to provide adequate dielectric strength at minimal  
10 operating voltages. The criteria are interrelated, as  
11 set forth below. Given a typical range of thickness for  
12 the phosphor layer ( $d_1$ ) of between about 0.2 and 2.0  
13 microns, a dielectric constant range for the phosphor  
14 layer ( $k_1$ ) of between about 5 and 10 and a dielectric  
15 strength range for the dielectric layer(s) of about  $10^6$   
16 to  $10^7$  V/m, the following relationships and calculations  
17 can be used to determine typical thickness ( $d_2$ ) and  
18 dielectric constant ( $k_2$ ) values for the dielectric layer  
19 of the present invention. These relationships and  
20 calculations may be used as guidelines to determine  $d_2$   
21 and  $k_2$  values, without departing from the intended scope  
22 of the present invention, should the typical ranges set  
23 out hereinabove change significantly.

24 The applied voltage V across a bilayer  
25 comprising a uniform dielectric layer and a uniform non-  
26 conducting phosphor layer sandwiched between two  
27 conductive electrodes is given by equation 1:

$$28 \quad V = E_2 * d_2 + E_1 * d_1 \quad (1)$$

29 wherein:

30  $E_2$  is the electric field strength in the  
31 dielectric layer;

32  $E_1$  is the electric field strength in the  
33 phosphor layer;

34  $d_2$  is the thickness of the dielectric layer;

35 and

36  $d_1$  is the thickness of the phosphor.

1 In these calculations, the electric field  
2 direction is perpendicular to the interface between the  
3 phosphor layer and the dielectric layer. Equation 1  
4 holds true for applied voltages below the threshold  
5 voltage at which the electric field strength in the  
6 phosphor layer is sufficiently high that the phosphor  
7 begins to break down electrically and the device begins  
8 to emit light.

9 From electromagnetic theory, the component of  
10 electric displacement D perpendicular to an interface  
11 between two insulating materials with different  
12 dielectric constants is continuous across the interface.  
13 This electric displacement component in a material is  
14 defined as the product of the dielectric constant and  
15 the electric field component in the same direction.  
16 From this relationship equation 2 is derived for the  
17 interface in the bilayer structure:

$$18 \quad k_2 * E_2 = k_1 * E_1 \quad (2)$$

19 wherein:

20  $k_2$  is the dielectric constant of the dielectric  
21 material; and

22  $k_1$  is the dielectric constant of the phosphor  
23 material.

24 Equations 1 and 2 can be combined to give  
25 equation 3:

$$26 \quad V = (k_1 * d_2 / k_2 + d_1) * E_1 \quad (3)$$

27 To minimize the threshold voltage, the first  
28 term in equation 3 needs to be as small as is practical.  
29 The second term is fixed by the requirement to choose  
30 the phosphor thickness to maximize the phosphor light  
31 output. For this evaluation the first term is taken to  
32 be one tenth the magnitude of the second term.  
33 Substituting this condition into equation 3 yields  
34 equation 4:

$$35 \quad d_2 / k_2 = 0.1 * d_1 / k_1 \quad (4)$$

36 Equation 4 establishes the ratio of the  
37 thickness of the dielectric layer to its dielectric

constant in terms of the phosphor properties. This thickness is determined independently from the requirement that the dielectric strength of the layer be sufficient to hold the entire applied voltage when the phosphor layer becomes conductive above the threshold voltage. The thickness is calculated using equation 5:

$$d_2 = V/S \quad (5)$$

wherein:

S is the strength of the dielectric material.

Use of the above equations and reasonable values for  $d_1$ ,  $k_1$ , and S provides the range of dielectric layer thickness and dielectric constant set forth in this specification and claims.

As stated previously, a second dielectric layer 20 is not needed if the first dielectric layer 22 provides a surface adjacent the phosphor layer which is sufficiently smooth (i.e. a subsequently deposited phosphor layer will illuminate generally uniformly at a given excitation voltage) and is compatible with the phosphor layer 22. Generally, a surface relief that does not vary more than about 0.5 microns over about 1000 microns (which equates approximately to a pixel width) is sufficient. A surface relief of 0.1 - 0.2 microns over that distance is more preferred. If the first dielectric layer 18 provides a sufficiently smooth surface, but does not provide the desired compatibility with the phosphor layer 22, a further layer of material (preferably, but not necessarily a dielectric material) to provide that compatibility may be added, for instance by thin film techniques.

In the event that the second dielectric layer 20 is needed, it is formed on the first dielectric layer 18. The second layer 20 may have a lower dielectric constant than that of the first dielectric layer 18 and will typically be formed as a much thinner layer (preferably greater than 2 microns and more preferably 2 - 10 microns). The desired thickness of second

1 dielectric layer is generally a function of smoothness,  
2 that is the layer may be as thin as possible, provided  
3 a smooth surface is achieved. To provide a smooth  
4 surface, sol gel deposition techniques are preferably  
5 used, followed by high temperature sintering. Sol gel  
6 deposition techniques are well understood in the art,  
7 see for example "Fundamental Principles of Sol Gel  
8 Technology", R.W. Jones, The Institute of Metals, 1989.  
9 In general, the sol gel process enables materials to be  
10 mixed on a molecular level in the sol before being  
11 brought out of solution either as a colloidal gel or a  
12 polymerizing macromolecular network, while still  
13 retaining the solvent. The solvent, when removed,  
14 leaves a solid with a high level of fine porosity,  
15 therefore raising the value of the surface free energy,  
16 enabling the solid to be sintered and densified at lower  
17 temperatures than obtainable using most other  
18 techniques.

19 The sol gel materials are deposited on the  
20 first dielectric layer 18 in a manner to achieve a  
21 smooth surface. In addition to providing a smooth  
22 surface, the sol gel process facilitates filling of  
23 pores in the sintered thick film layer. Spin deposition  
24 or dipping are most preferred. These are techniques  
25 used in the semiconductor industry for many years,  
26 mainly in photolithography processes. For spin  
27 deposition, the sol material is dropped onto the first  
28 dielectric layer 18 which is spinning at a high speed,  
29 typically a few thousand RPM. The sol can be deposited  
30 in several stages if desired. The thickness of the  
31 layer 20 is controlled by varying the viscosity of the  
32 sol gel and by altering the spinning speed. After  
33 spinning, a thin layer of wet sol gel is formed on the  
34 surface. The sol gel layer 20 is sintered, generally at  
35 less than 1000°C, to form a ceramic surface. The sol may  
36 also be deposited by dipping. The surface to be coated  
37 is dipped into the sol and then pulled out at a constant

1 speed, usually very slowly. The thickness of the layer  
2 is controlled by altering the viscosity of the sol and  
3 the pulling speed. The sol may also be screen printed  
4 or spray coated, although it is more difficult to  
5 control the thickness of the layer with these  
6 techniques.

7 The material used in the second dielectric  
8 layer 20 is preferably a ferroelectric ceramic material,  
9 preferably having a perovskite crystal structure to  
10 provide a high dielectric constant. The dielectric  
11 constant is preferably similar to that of the first  
12 dielectric layer material in order to avoid voltage  
13 fluctuations across the two dielectric layers 18, 20.

14 However, with a thinner layer being utilized in the  
15 second dielectric 20, a dielectric constant as low as  
16 about 20 may be used, but will preferably be greater  
17 than 100. Exemplary materials include lead zirconate  
18 titanate (PZT), lead lanthanum zirconate titanate  
19 (PLZT), and the titanates of Sr, Pb and Ba used in the  
20 first dielectric layer 18, PZT and PLZT being most  
21 preferred.

22 PZT or PLZT are preferably deposited as a sol  
23 gel by spin deposition followed by sintering at less  
24 than about 600°C, to form a smooth ceramic surface  
25 suitable for deposition of the next layer.

26 The next layer to be deposited will typically  
27 be the phosphor layer 22, however, as set out  
28 hereinabove, it is possible, within the scope of this  
29 invention to include a further layer above the second  
30 dielectric layer 20 to further improve the interface  
31 with the phosphor layer. For instance, a thin film  
32 layer of material known to provide good injectivity and  
33 compatibility may be used.

34 The phosphor layer 22 is deposited by known  
35 thin film deposition techniques such as vacuum  
36 evaporation with an electron beam evaporator, sputtering  
37 etc. The preferred phosphor material is ZnS:Mn, but

1 other phosphors that emit light of different colours are  
2 known. The phosphor layer 22 typically has a thickness  
3 of about 0.5 microns and a dielectric constant between  
4 about 5 and 10.

5 A further transparent dielectric layer above  
6 the phosphor layer 22 is not needed, but may be included  
7 if desired.

8 The front electrode layer 24 is deposited  
9 directly on the phosphor layer 22 (or the further  
10 dielectric layer if included). The front electrode is  
11 transparent and is preferably formed from indium tin  
12 oxide (ITO) by known thin film deposition techniques  
13 such as vacuum evaporation in an electron beam  
14 evaporator.

15 The laminate 10 is typically annealed and then  
16 sealed with a sealing layer 26, such as glass.

17 A preferred laminate, from rear to front, with  
18 typical thickness values in accordance with the present  
19 invention is as follows:

20 Substrate Layer - Alumina

21 Rear Electrode - Ag/Pt Address lines - 10 microns

22 First Dielectric Layer - Lead Niobate - 30 microns

23 Second Dielectric Layer - Lead Zirconate Titanate - 2  
24 microns

25 Phosphor Layer - ZnS:Mn - 0.5 microns

26 Front Electrode - ITO - 0.1 microns

27 Sealing Layer - Glass - 10 - 20 microns.

28 In larger EL displays, the thicknesses of the  
29 layers may vary. For instance, the sol gel layer  
30 thickness is typically increased to about 6-10 microns  
31 to provide the desired smoothness. Similarly, the ITO  
32 layer thickness might be increased up to 0.3 microns in  
33 a larger display.

34 In accordance with the present invention the  
35 connection of the front and rear address lines of an  
36 electroluminescent laminate to the voltage driver  
37 circuit is preferably achieved using the through hole in  
38 the rear substrate. Most preferably, the EL laminate

1 includes the thick dielectric layer of this invention,  
2 although this is not necessary.

3 Voltage driver circuitry includes voltage  
4 driving components (typically referred to as high  
5 voltage driver chips), the outputs of which are  
6 connected to the individual row and column address lines  
7 of the rear and front electrodes in order to selectively  
8 activate pixels in accordance with the video input  
9 signals. The voltage driver circuitry and components  
10 are generally known in the art. To illustrate the  
11 present invention, through hole connections were  
12 provided for known packaged high voltage driver chips  
13 which are to be surface mounted on the rear substrate by  
14 known reflow soldering techniques. Such high voltage  
15 driver chips are known for the conventional symmetric  
16 pulse driving schemes and for asymmetric pulse driving  
17 schemes.

18 However, it will be realized by those skilled  
19 in the art that the particular driver circuitry or  
20 driver components may be varied and as such will  
21 naturally affect the patterns of through holes and the  
22 circuit patterns provided for connection to the driver  
23 circuitry. The invention has application whether the  
24 entire driving circuit or only a portion thereof is to  
25 be mounted on the rear substrate. For instance, instead  
26 of using the high voltage packaged chips, it is possible  
27 to use bare silicon die (chips) on the substrate using  
28 conventional die attach methods, and using conventional  
29 wirebonding techniques to connect the chips to the drive  
30 circuitry on the substrate. In this case, the driver  
31 chips would occupy much less area on the substrate and  
32 it would be possible to place all of the drive circuitry  
33 on the substrate. The result is an ultrathin display  
34 panel that could be interfaced directly to a video  
35 signal and connected directly to a dc power supply.  
36 Such displays would be useful in ultrathin portable  
37 products that require a display. Of course, the ability



1 to mount driving circuitry on the rear of the substrate  
2 is tied to the overall size of the display, a larger  
3 display providing more space for the drive circuitry  
4 directly on the rear of the substrate.

5 The circuit connection aspect of this  
6 invention is illustrated in Figures 3 - 10. As  
7 indicated above, particular through hole and circuit  
8 patterns are provided for illustration purposes for  
9 mounting high voltage driver chips 30 on the reverse  
10 side of the rear substrate. The particular chips chosen  
11 were Supertex HV7022PJ chips to connect to the row  
12 address lines 14 and Supertex HV8308PJ and HV8408PJ  
13 (Supertex Inc. is located in Sunnyvale, California) for  
14 connection to the column address lines 24. The latter  
15 two chips differ in that the lead pattern of one is a  
16 mirror image of the lead pattern of the other.

17 Referring to the Figures, the EL laminate 10  
18 is preferably, but not necessarily, constructed with the  
19 two layer dielectric layers 18, 20 of this invention,  
20 and is thus constructed from the rear substrate 12  
21 toward the front viewing side. The rear substrate 12 is  
22 drilled with through holes 32 in a pattern such that  
23 they will be proximate the ends of the address lines 14,  
24 24 (subsequently formed). Alternatively, additional  
25 through holes could be provided in a spaced relationship  
26 along the address lines. This would be useful to  
27 provide connection to front ITO address lines which have  
28 high resistivity. The pattern of Figure 4 provides for  
29 connection to an EL laminate 10 on a rectangular  
30 substrate 12, with row address lines (rear electrode) 14  
31 along the longer dimension and column address lines  
32 (front electrode) 24 along the shorter dimension.

33 The through holes 32 are preferably formed by  
34 laser. The holes 32 are typically wider on one side due  
35 to the nature of the laser drilling process, that side  
36 being chosen to be the rear or reverse side to  
37 facilitate flowing conductive material into the holes.

1                   The substrate 12 used in the EL laminate  
2 should be one which can withstand the temperatures  
3 encountered in the subsequent processing steps.  
4 Typically substrates used are those which provide  
5 sufficient rigidity to support the laminate and which  
6 are stable to temperatures of 850°C or greater to  
7 withstand the subsequent firing sintering steps for the  
8 thick film pastes and sol gel materials. The substrate  
9 should also be opaque to laser light, to allow the  
10 through holes 32 to be formed by laser drilling.  
11 Finally, the substrate should provide for good adherence  
12 of the thick film pastes used in subsequent steps.  
13 Crystalline ceramic materials and opaque vitreous  
14 materials may be used. Alumina is particularly  
15 preferred.

16                   A circuit pattern 34 of conductive material is  
17 printed on the rear side of the substrate 12 in the  
18 pattern shown in Figure 5. In this step, the conductive  
19 material is pulled through the through holes 32 in a  
20 manner to be discussed. The circuit pattern 34 on the  
21 rear side of the substrate 12 consists of rear connector  
22 pads 36 around each of the through holes 32, chip  
23 connector pads 38 for the outputs of the high voltage  
24 driver chips (not shown), further connector pads (not  
25 labelled) for connection to the rest of the drive  
26 circuit (not shown), and electrical leads (not labelled)  
27 between numerous of the connector pads as shown.

28                   The conductive material is preferably a  
29 conductive thick film paste applied by screen printing.  
30 Silver/platinum thick film pastes are preferred.

31                   To form a conductive path through each through  
32 hole 32, a vacuum is applied on the front side of the  
33 substrate 12 while the circuit 34 is printed on the rear  
34 side. This is preferably accomplished by placing the  
35 substrate 12 on a vacuum table with a master plate  
36 having holes drilled in the pattern of Figure 4 between  
37 the substrate 12 and the vacuum. The holes in the master

1 plate are aligned with and somewhat larger than the  
2 holes in the substrate 12. The vacuum is not applied  
3 until the circuit is printed to ensure that the vacuum  
4 is uniformly applied. The vacuum is continued until  
5 conductive material is pulled through to the front side  
6 of the substrate. At that point, a small amount of the  
7 conductive material is pulled through to the front side  
8 of the substrate 12 and the through hole walls are  
9 coated. The thick film paste is then fired in  
10 accordance with known procedures.

11 Following this step a circuit pad  
12 reinforcement pattern 42 is preferably, but not  
13 necessarily, printed as shown in Figure 7. Similar  
14 conductive materials, printing and firing steps are  
15 followed.

16 The row address lines 14 and connector pads  
17 40a and 40b are then formed on the front side of the  
18 substrate 12, preferably by screen printing a thick film  
19 conductive paste such as a silver/platinum paste. The  
20 address line pattern is shown in Figure 6 to include  
21 rows extending along the length of the substrate 12 and  
22 ending at the front (row) connector pads 40a. During  
23 this same step, the front (column) connector pads 40b  
24 are printed to provide for ultimate connection of the  
25 column address lines to the driving circuitry via the  
26 through holes 32. The conductive paste is preferably  
27 pulled through the through holes 32 as above, with the  
28 vacuum being applied from the rear, circuit side of the  
29 substrate.

30 While the means forming a conductive path  
31 through the through holes 32 has been set out above to  
32 be formed from thick film conductive pastes, the  
33 conductive paths might also be formed as electroplated  
34 through holes, or as through holes formed by electroless  
35 plating, as is known in the art, provided the  
36 electroplated material adheres properly to the substrate

1 and that subsequent layers adhere to the plated  
2 conductor.

3 The thick film dielectric layer 18 of this  
4 invention is then preferably formed and fired in the  
5 manner set out above.

6 The rear circuit side of the substrate is then  
7 preferably sealed, with a rear sealant 44, for instance  
8 by screen printing with a thick film glass paste,  
9 leaving the connector pads exposed for attachment of the  
10 high voltage driver chips and connector pins 45 to the  
11 rest of the driver circuitry (not shown). The sealing  
12 pattern is shown in Figure 8.

13 The EL laminate is then completed with the sol  
14 gel-layer 20, the phosphor layer 22 and the front column  
15 address lines 24, as described above. The pattern for  
16 the front column address lines 24 is shown in Figure 9  
17 to consist of parallel columns across the width of the  
18 substrate 12 ending proximate the front (column)  
19 connector pads 40.

20 Electrical interconnects 46 between the column  
21 address lines 24 and the front (column) connector pads  
22 40 are provided, if necessary, for reliable electrical  
23 connection. These are preferably formed by printing a  
24 conductive material such as silver through a shadow mask  
25 in the pattern shown in Figure 10.

26 A front sealing layer 26 as previously  
27 described is provided to prevent moisture penetration.

28 In accordance with the present invention, the  
29 front ITO address lines 24 of the EL laminate 10 are  
30 preferably formed by laser scribing. This laser  
31 scribing technique is set forth hereinbelow in  
32 connection with the preferred EL laminate 10 of this  
33 invention. However, it should be understood that the  
34 laser scribing technique has broader application in  
35 patterning a planar laminate having overlying and  
36 underlying layers. In that respect, the ITO and  
37 phosphor layers 24, 22 are illustrative of overlying

1 layers which do not absorb the laser light to any  
2 substantial extent, and the thick film lead niobate  
3 dielectric layer 18 and the sol gel layer 20 of lead  
4 zirconate titanate are illustrative of underlying layers  
5 that do absorb the laser light. Other typical materials  
6 used as transparent conductors include  $\text{SnO}_2$  and  $\text{In}_2\text{O}_3$ .

7 Generally, in the broad context of the  
8 invention, the overlying layer is a material which is  
9 transparent to visible light and the underlying layer is  
10 a material which is opaque to visible light. The  
11 underlying material can then be directly ablated, and  
12 the overlying material indirectly ablated, by utilizing  
13 a laser beam with a wavelength in the visible or  
14 infrared region of the electromagnetic spectrum. This  
15 laser ablation method has broad application in  
16 patterning transparent conductive layers in  
17 semiconductors, liquid crystal displays, solar cells,  
18 and EL displays.

19 In order to control the precision and  
20 resolution of the laser scribing (depth and width of  
21 cuts), to avoid explosive delamination of the layers and  
22 to minimize interdiffusion between the layers, certain  
23 properties of the materials and thicknesses of the  
24 layers should be observed.

25 In respect of a two layer laminate, the  
26 following relationship should hold:

$$27 \quad \alpha_u T_u > \alpha_o T_o,$$

28 wherein:

29  $\alpha_u$  = absorption coefficient of underlying layer;

30  $\alpha_o$  = absorption coefficient of overlying layer;

31  $T_u$  = thickness of underlying layer; and

32  $T_o$  = thickness of overlying layer.

33 More preferably, the product of  $\alpha_u T_u$  is very  
34 much greater than the product of  $\alpha_o T_o$ .

35 When there is a plurality of overlying  
36 transparent layers and/or a plurality of underlying  
37 opaque layers, the sum of the product of  $\alpha_u T_u$  for each

1 layer should be greater than the sum of the product of  
2  $\alpha_o T_o$  for each layer, i.e.

$$3 \quad \sum_i \alpha_{o_i} T_{o_i} > \sum_i \alpha_o T_o_i$$

5 If the above relationship is maintained, it  
6 should be possible to directly ablate only a portion of  
7 the underlying layer, without cutting through its entire  
8 thickness, and indirectly ablate through the entire  
9 thickness of the overlying layer, in accordance with the  
10 process of the invention.

11 Explosive delamination can result if heat or  
12 vapour pressure builds up in the underlying layer before  
13 the overlying layer can soften and/or vaporize by  
14 indirect ablation. Thus, the material in the overlying  
15 layer should melt and vaporize at a lower temperature  
16 than does the material in the underlying layer.

17 To enhance the ability to make high resolution  
18 cuts, the thermal conductivity of the material in the  
19 underlying layer is preferably less than that of the  
20 material in the overlying layer. The thermal  
21 conductivities of both layers should be such that  
22 significant heat does not flow away from the region  
23 being ablated in the time during which that region is  
24 exposed to the laser beam.

25 To avoid mass interdiffusion between layers,  
26 the diffusion time for such processes should be greater  
27 than the time during which the region to be ablated is  
28 exposed to the laser beam.

29 The above preferred properties are generally  
30 known for materials, making it possible to predict which  
31 materials are amenable to the laser scribing process of  
32 this invention.

33 Resolution of the laser cuts, explosive  
34 delamination and interdiffusion are also affected by the  
35 wavelength, power and scanning speed of the laser beam.  
36 However if the above relationships and properties are  
37 generally maintained, these other laser conditions can  
38 be controlled and varied to achieve the desired results  
39 of direct and indirect ablation.

1 Lasers are known which provide a laser beam  
2 with a wavelength in the visible or infrared region.  
3 Carbon dioxide lasers, argon lasers and YAG lasers are  
4 exemplary. All have wavelengths greater than about 400  
5 nm. Pulsed or continuous wave (CW) lasers may be used,  
6 the latter being preferred to provide sharp, high  
7 resolution cuts. The laser beam is focused by  
8 appropriate known lens systems to achieve the desired  
9 resolution and to ensure sufficient local power density  
10 for complete removal of overlying layer. Generally, the  
11 power density of the laser beam is set so that the  
12 groove which is cut is significantly greater than the  
13 thickness of the overlying transparent layers. When the  
14 transparent layer comprises electrode address lines,  
15 this ensures that the address lines are clearly defined  
16 and electrically isolated.

17 Scribing can be performed either by moving the  
18 laser beam with respect to the material being scribed or  
19 more preferably, by mounting the material to be scribed  
20 on an X-Y coordinates table that is moveable relative to  
21 the laser beam. For scribing address lines, a table  
22 moveable in the X direction (i.e. perpendicular to the  
23 lines being scribed) is preferred, the laser beam being  
24 moveable in the Y direction, i.e. along the lines.

25 Material which is vaporized or decomposed  
26 during the laser scribing process may be drawn away from  
27 the material being scribed by a vacuum located proximate  
28 to the laser beam.

29 In the preferred EL laminate 10 of the present  
30 invention, a thin layer of indium tin oxide 24 is  
31 deposited by known methods above the phosphor layer 22.  
32 Vacuum deposition methods or sol gel methods to deposit  
33 ITO are disclosed in U.S. Patents 4,568,578 and  
34 4,849,252. Materials other than ITO may be used, for  
35 example fluorine doped tin oxide. An optional  
36 transparent dielectric layer can be provided between the  
37 ITO and phosphor layers 24, 22. The preferred sol gel  
38 layer 20 of PZT and the thick film dielectric layer 18  
39 of lead niobate underlie the phosphor layer. The EL

1 laminate 10 is formed in reverse sequence to  
2 conventional TFEL devices, as described hereinabove.  
3 This conveniently leaves the ITO layer 24 and the  
4 phosphor layer 22 as upper (overlying) transparent  
5 layers above lower (underlying) opaque dielectric layers  
6 18, 20 (lead niobate and PZT), amenable to laser  
7 scribing in accordance with the present invention.

8 The individual column address lines 24 are  
9 laser scribed, as described above. The laser beam  
10 directly ablates at least a portion of the sol gel layer  
11 20 and possible a minor portion of the thick underlying  
12 dielectric layer 18 and indirectly ablates the ITO and  
13 phosphor layers 24, 22 throughout their thicknesses.  
14 This leaves a reliable insulating gap between the  
15 adjacent address lines.

16 The column address lines 24 are connected to  
17 the driving circuitry as described above. More  
18 particularly, in accordance with the preferred through  
19 hole connecting process described above, the electrical  
20 interconnects 46 are formed (prior to laser scribing) by  
21 evaporating silver in the pattern shown in Figure 10 in  
22 locations to overlap the portions of the ITO layer which  
23 will ultimately form the address lines. The address  
24 lines are then scribed in the manner set out above.

25 The completed EL laminate 10 can be sealed as  
26 described above by spraying a protective polymer sealant  
27 on the front viewing surface or by bonding a glass plate  
28 26 to the front surface.

29 Several advantages are derived by using  
30 indirect ablation to scribe transparent conductor  
31 materials. A relatively low power continuous wave laser  
32 producing light in the visible range can be used rather  
33 than an ultraviolet pulsed laser with a high  
34 instantaneous power output. This not only reduces laser  
35 costs, but produces smoother edges on the ablated cuts.  
36 This is particularly important for high resolution EL  
37 displays. Direct ablation of transparent materials  
38 requires very high instantaneous laser power to deposit  
39 the energy necessary for the ablation in a time short



1 enough to prevent diffusion of heat away from the area  
2 where ablation is to occur. In prior art attempts to  
3 directly ablate a transparent conductor deposited on a  
4 transparent substrate, only a small fraction of the  
5 laser power is directly absorbed by the transparent  
6 conductor material; most of the light passes through  
7 both transparent layers. In many cases, indirect  
8 ablation can minimize the problem of interdiffusion  
9 between layers, since the heating to vaporize the  
10 transparent layers occurs from the bottom of the  
11 transparent layers. This promotes the removal of  
12 ablated material outwardly and upwardly in the stream of  
13 vaporized material, rather than diffusion of the  
14 material into the underlying layer. This is  
15 particularly important in order to preserve the quality  
16 of the dielectric and phosphor layers in EL displays.

17 The present invention is further illustrated  
18 by the following non-limiting examples.

19 EXAMPLE 1

20 This example is included to illustrate that  
21 simply screen printing a thick film layer of barium  
22 titanate (the material used as a ceramic sheet in the  
23 Miyata et al. references) is subject to electric  
24 breakdown under operating conditions of about 200V.

25 A single pixel electroluminescent device was  
26 constructed on an alumina substrate (5 cm square, 0.1 cm  
27 thick) obtained from Coors Ceramics (Grand Junction,  
28 Colorado, U.S.A.). A rear electrode layer was applied,  
29 centered on the substrate, but spaced from the edges.  
30 The material used was a silver/platinum conductor which  
31 was printed as address lines as is conventional in  
32 electronics. More particularly, Cermalloy # C4740  
33 (available from Cermalloy, Conshohocken, Pa.) was screen  
34 printed as a thick film paste through a 320 mesh  
35 stainless steel screen and coated with an emulsion. The  
36 emulsion was exposed to ultraviolet light through a  
37 photomask, so as to expose those areas of the emulsion  
38 that were to be retained for printing. The unexposed  
39 emulsion was dissolved away with water where paste was

1 to be printed through the screen. The remaining  
2 emulsion was then further hardened with additional light  
3 exposure. The printed paste was dried in an oven at  
4 150°C for a few minutes and fired in air in a BTU model  
5 TFF 142-790A24 belt furnace with a temperature profile  
6 as recommended by the paste manufacturer. The maximum  
7 processing temperature was 850°C. The resulting  
8 thickness of the fired electrode conductor layer was  
9 about 9 microns.

10 A dielectric layer was formed on this  
11 electrode layer as follows. A dielectric paste  
12 comprising barium titanate (ESL # 4520 - available from  
13 Electrosience Laboratories, King of Prussia,  
14 Pennsylvania, dielectric constant 2500 - 3000) was  
15 printed through a 200 mesh screen in a square pattern so  
16 that all but an electrical contact pad at the edge of  
17 the electrode was covered. The printed dielectric paste  
18 was fired in air in the BTU furnace with a temperature  
19 profile as recommended by the manufacturer (maximum  
20 temperature 900 - 1000°C). The thickness of the  
21 resulting fired dielectric was in the range of 12 to 15  
22 microns. A second and third layer of the dielectric  
23 were then printed and fired over the first layer in the  
24 same manner. The combined thickness of the three  
25 printed and sintered dielectric layers was 40 to 50  
26 microns.

27 A phosphor layer was deposited directly onto  
28 the dielectric layer in accordance with known thin film  
29 techniques. In particular, a 0.5 micron thick layer of  
30 zinc sulphide doped with 1 mole percent of manganese was  
31 evaporated onto the dielectric layer using a UHV  
32 Instruments Model 6000 electron beam evaporator. The  
33 layers were heated under vacuum in the evaporator and  
34 were held at a temperature of 150°C during the  
35 evaporation process which took approximately 2 minutes.

36 The phosphor layer was coated with a 0.5  
37 micron layer of a transparent electrical conductor  
38 consisting of indium tin oxide. This layer was applied

1 by known thin film deposition techniques, in particular  
2 using the electron beam evaporator at 400°C under vacuum.

3 The laminate was subsequently annealed in air  
4 for 15 minutes at 450°C to anneal the phosphor and indium  
5 tin oxide conductor layers. An indium solder contact  
6 was provided to the ITO layer. The device was sealed  
7 with a silicone sealant (Silicone Resin Clear Lacquer,  
8 cat.#419, from M.G. Chemicals).

9 The device was tested by applying a DC voltage  
10 of 200 volts across the two electrodes. The device was  
11 observed to fail upon application of the voltage due to  
12 electrical breakdown of the dielectric layer in the  
13 region immediately surrounding the contact to the indium  
14 tin oxide.

15 Without being bound by same, it is believed  
16 that the failure of the device was because the  
17 dielectric layer did not provide the needed smooth  
18 surface for the phosphor layer. Microcracks could be  
19 observed at the surface. This may, however, be due to  
20 the presence of deleterious materials in the commercial  
21 dielectric paste and is thus not an indication that  
22 barium titanate cannot be used as a single or first  
23 dielectric layer in accordance with the present  
24 invention.

#### 25 EXAMPLE 2

26 This example is included to illustrate that a  
27 screen printed dielectric layer from a paste containing  
28 lead niobate, a material known to have a high dielectric  
29 constant and a lower sintering temperature than barium  
30 titanate, provides adequate dielectric strength, but  
31 does not luminesce.

32 A device was constructed that was similar to  
33 that in Example 1, but having a dielectric layer formed  
34 from a dielectric paste of lead niobate, Cermalloy #  
35 IP9333 (dielectric constant about 3500, thickness as in  
36 Example 1). The device, when tested was not subject to  
37 dielectric breakdown when a DC voltage of 400 volts was  
38 applied. However, it failed to luminesce on application  
39 of an AC voltage.

1 Without being bound by the same it is believed  
2 that the failure to luminesce was due to compatibility  
3 problems at the interface with the phosphor layer. Thus  
4 this example should not be taken as an indication that  
5 lead niobate cannot be used as single or first  
6 dielectric layer in accordance with the present  
7 invention.

8 EXAMPLE 3

9 This example illustrates a two layer  
10 dielectric constructed in accordance with the present  
11 invention, with a first dielectric layer of lead niobate  
12 (as in Example 2) and a second dielectric layer of lead  
13 zirconate titanate. Favourable luminescence was  
14 achieved.

15 A device identical to that in Example 2 was  
16 constructed, but with the additional step of applying a  
17 layer of lead zirconate titanate (PZT) using a sol gel  
18 process to the printed and fired dielectric layer before  
19 the phosphor layer was applied. The sol was prepared in  
20 the following manner. Acetic acid was dehydrated at  
21 105°C for 5 minutes. Twelve grams of lead acetate was  
22 dissolved into 7 ml. of the dehydrated acid at 80°C to  
23 form a colourless solution. The solution was allowed to  
24 cool, and 5.54 g of zirconium propoxide was stirred into  
25 the solution to form a pale yellow solution. The  
26 solution was held at 60°C to 80°C for five minutes after  
27 which 2.18 g of titanium isopropoxide was added with  
28 stirring. The resulting solution was agitated for  
29 approximately 20 minutes in an ultrasonic bath to ensure  
30 that any remaining solids were dissolved. Then,  
31 approximately 1.75 ml of a 4:2:1 ethylene glycol to  
32 propanol to water solution was added to make a stable  
33 sol. More ethylene glycol was added before coating to  
34 adjust the viscosity to the desired value for spin  
35 coating or dipping. The prepared dielectric layer was  
36 spin coated in one case and dipped in another case with  
37 the sol. In the case of spin coating the sol was  
38 dribbled onto the first dielectric layer which was  
39 spinning in a horizontal plane at 3000 rpm. In the case

1 of dipping, a higher viscosity sol was used. For the  
2 dipping procedure the substrate was pulled from the sol  
3 at a rate of 5 cm per minute. The resulting coated  
4 assembly was then heated in air in an oven at a  
5 temperature of 600°C for 30 minutes to convert the sol to  
6 PZT. The thickness of the PZT layer was approximately  
7 2 to 3 microns. The surface of the PZT layer was  
8 observed to be considerably smoother than that of the  
9 screen printed and sintered first dielectric layer.

10 Following application of the PZT layer, the  
11 phosphor and transparent conductor layers were deposited  
12 as in Example 1.

13 The completed laminate performed well with  
14 luminosity versus voltage characteristics similar to or  
15 better than those reported by Miyata et al. The  
16 threshold voltage for minimum luminance for the display  
17 was 110 V. Luminosity at 50 volts above threshold (i.e.  
18 160 volts, 60 Hz) was 57 foot Lamberts.

#### 19 EXAMPLE 4

20 This example is included to illustrate that  
21 variations in the thickness of the dielectric layer have  
22 an effect on both the operating voltage and the  
23 luminance of the displays.

24 A display was constructed as in Example 3,  
25 except that only two instead of three screen printed  
26 layers of dielectric were applied. The thickness of the  
27 first dielectric layer was correspondingly reduced to 25  
28 to 30 microns.

29 The display functioned well. The threshold  
30 voltage for minimum luminance was 70 volts (cp 110 volts  
31 in Example 3), expected from theoretical considerations.  
32 The luminosity at 50 volts above the threshold value  
33 also decreased to 35 foot Lamberts (cp 57 foot Lamberts  
34 in Example 3).

#### 35 Example 5

36 This example illustrates the preferred  
37 embodiment of connecting the row and column address  
38 lines of the EL laminate to the driver circuit using  
39 through holes.

1                   An addressable EL display was constructed  
2 using the same sequence of layer depositions as set  
3 forth in Example 3. The substrate was a 0.025 inch  
4 thick rectangle of alumina obtained from Coors Ceramics  
5 (Grand Junction, Colorado, U.S.A.) having dimensions of  
6 length - 6 inches and width - 2 inches. The substrate  
7 was drilled with 0.006 inch diameter through holes using  
8 a carbon dioxide laser in the pattern shown in Figure 4.  
9 The substrate was inspected to ensure that all of the  
10 holes were clear. The holes were found to be about  
11 0.008 inches in diameter on the side facing the laser  
12 and about 0.006 inches on the opposite side. The side  
13 with the wider hole openings was chosen to be the rear  
14 side of the substrate to facilitate flowing conductive  
15 material into the through holes.

16                   Following this, the circuit pattern shown in  
17 Figure 5 was printed onto the rear side of the substrate  
18 through a 325 mesh stainless steel screen using  
19 Cermalloy #4740 silver platinum paste. During the  
20 printing process, the substrate was aligned with a  
21 master plate having 0.040 inch holes drilled in the same  
22 pattern as shown in Figure 4 and a vacuum was applied  
23 below the master plate to pull the conductive paste  
24 through the through holes in the substrate (i.e. through  
25 to the front, viewing side of the substrate). This step  
26 formed the circuit pattern of Figure 5 together with a  
27 conductive path through each of the through holes in the  
28 substrate. To ensure uniformity in the application of  
29 the vacuum, the vacuum was not turned on until the  
30 substrate had been printed. The part was inspected to  
31 ensure that the through holes were filled.

32                   Following printing, the substrate was fired in  
33 air in a BTU model TFF 142-790A24 belt furnace with a  
34 temperature profile recommended by the paste  
35 manufacturer. The maximum temperature was 850°C.

36                   Following this step, a circuit reinforcement  
37 pattern as shown in Figure 7 was printed and fired on  
38 the rear, circuit side of the substrate (using the same  
39 Cermalloy conductive paste). This step made the circuit

1 pattern thicker in certain areas where electrical  
2 connections were to be subsequently made.

3 The row address lines and the front row and  
4 column connector pads were then screen printed on the  
5 front viewing side of the substrate. The lines extended  
6 across the length of the substrate to the row connector  
7 pads in the pattern shown in Figure 6. The column  
8 connector pads, as shown in Figure 6, were printed in  
9 this same step. The row address lines and connector  
10 pads were formed from the same conductive paste  
11 (Cermalloy #4740) using the same printing and firing  
12 conditions. The substrate was positioned on the same  
13 master plate with the through hole pattern of Figure 4  
14 and a vacuum was applied from below to pull the  
15 conductive paste through the through holes toward the  
16 rear side of the substrate. The thickness of the fired  
17 electrode layer was about 8 micrometers. There were  
18 about 52 address lines per inch and the total number of  
19 address lines was 68. The part was examined to ensure  
20 the through holes were filled.

21 The three layers of the dielectric paste  
22 (Cermalloy #IP9333) were printed and fired as set forth  
23 in Example 3 to form a dielectric layer of about 50  
24 micrometers thickness.

25 The rear, circuit side of the substrate was  
26 then sealed. A thick film glass paste (Heraeus IP9028,  
27 from Heraeus-Cermalloy, Conshohocken, Pa.) was screen  
28 printed using a 250 mesh screen in the pattern shown in  
29 Figure 8. The connector pads for connection to the high  
30 voltage driver chips and other driver circuitry were  
31 left uncovered. The glass sealing layer was then fired  
32 in the BTU belt furnace using a temperature profile  
33 recommended by the manufacturer with a maximum  
34 temperature of 700°C.

35 During the above mentioned firing steps, the  
36 substrate was supported on pieces of ceramic material at  
37 either end to avoid contact between the printed material  
38 on the circuit side and the belt of the furnace.

1           The sol gel layers were then formed by dipping  
2 substantially as set out in Example 3. Three or four  
3 sol gel layers were typically used, with pulling rates  
4 of 10 - 25 sec/in from a mixture having a viscosity of  
5 about 100 cp as measured by the falling ball viscometer.  
6 Between dipping layers, the sol gel was dried at 110°C  
7 for 10 min. A vacuum chuck was placed over the active  
8 area of the laminate and the sol gel was water washed  
9 off the remaining areas. The layer was then fired at  
10 about 600°C in a belt furnace for 25 min. A total sol  
11 gel thickness between 3 - 10 micrometres was achieved.  
12 This was followed by the phosphor layer of Example 3  
13 using zinc sulfide doped with 1% manganese with a  
14 thickness of 0.5 - 1.0 micrometers.

15           The column address lines were then deposited  
16 from indium tin oxide, as described in Example 3, in the  
17 pattern shown in Figure 9. There were about 52 column  
18 address lines per inch and a total of 256 columns. The  
19 spacing between the lines was 0.001 inches and the line  
20 width was 0.019 inches (center to center).

21           Silver was evaporated through a shadow mask in  
22 the pattern shown in Figure 10 to make the electrical  
23 connections of the column address lines to the column  
24 connector pads and through hole conductors on the  
25 substrate.

26           The viewing surface of the laminate was sealed  
27 with a silicone sealant sprayed over the entire front  
28 face of the display. The sealant used was Silicone  
29 Resin Clear Lacquer, Cat. #419 from M.G. Chemicals.

30           The completed display was tested by connecting  
31 a pulse generator providing a 160V square wave signal at  
32 60 Hz across pairs of row and column pads on the circuit  
33 deposited on the rear of the substrate. Each pixel of  
34 the display was found to light up independently and with  
35 a consistent intensity equal to that measured in Example  
36 3 when the voltage was applied. No dysfunctional pixels  
37 were found among the total pixel count of 17408.



## EXAMPLE 6

This example illustrates the preferred embodiment of laser scribing the indium tin oxide address lines of the EL laminate of the present invention.

An addressable matrix display was constructed on a ceramic substrate using the following procedure. The substrate was a 0.025 inch thick rectangle of alumina with length 6 inches and width 2 inches obtained from Coors Ceramics (Grand Junction, Colorado, U.S.A.). This was drilled with 0.006 inch diameter holes with a carbon dioxide laser in the pattern shown in Figure 4. The part was inspected to ensure that all of the holes were clear.

Following this step, the circuit pattern shown in Figure 5 was printed through a 325 mesh stainless steel screen using Cermalloy (Conshohocken Pennsylvania, U.S.A.) #4740 silver platinum paste. During the printing process, the substrate was aligned with a master plate having 0.040 inch holes drilled in the same pattern as the substrate to facilitate applying a vacuum to the substrate holes during printing. The vacuum sucked paste through the holes to facilitate the formation of a conductive path through the ceramic substrate after the part was fired. The part was fired in air in a BTU model TFF 142-790A24 belt furnace with a temperature profile recommended by the paste manufacturer, having a maximum temperature of 850°C.

Following this step, a circuit reinforcement pattern as shown in Figure 7 was printed and fired on the rear, circuit side of the substrate (using the same Cermalloy conductive paste). This step made the circuit pattern thicker in certain areas where electrical connections were to be subsequently made.

Following this, a set of row address lines and connector pads were printed on the front viewing side of the substrate. The lines extended along the length of the substrate to the row connector pads (as shown in Figure 6). The column connector pads were also formed

1 in this step (as shown in Figure 6). The row address  
2 lines and the row and column connector pads were formed  
3 from the same silver platinum paste using the same  
4 printing and firing conditions. The substrate was  
5 positioned on the same master plate with the through  
6 hole pattern of Figure 4 and a vacuum was applied from  
7 below to pull the conductive paste through the through  
8 holes toward the rear side of the substrate. The  
9 thickness of the fired electrode layer was about 8  
10 micrometers. There were 52 address lines per inch and  
11 the total number of address lines was 68.

12 Next three layers of lead niobate dielectric  
13 paste (Cermalloy #IP9333) were sequentially printed and  
14 fired in the belt furnace with a temperature profile as  
15 recommended by the manufacturer (maximum temperature  
16 850C) on top of the row address lines (as set forth in  
17 Example 3). The combined thickness of the dielectric  
18 layers was 50 micrometers.

19 Following this, the rear, circuit side of the  
20 substrate was sealed as set forth in Example 5, in the  
21 pattern shown in Figure 8.

22 Next, a 3 - 10 micrometer thick layer of lead  
23 zirconate titanate (PZT) was deposited on the lead  
24 niobate layer to form a smooth surface. The sol gel  
25 technique using dipping, as set out in Example 5, was  
26 used. A thin film phosphor layer was then deposited  
27 using electron beam evaporation methods as known in the  
28 art. The phosphor layer was zinc sulfide doped with 1%  
29 manganese, which was deposited to a thickness of between  
30 0.5 and 1 micrometers.

31 The next step was to deposit a 300 nanometre  
32 thick layer of indium tin oxide (ITO) on the phosphor  
33 layers using electron beam evaporation methods as known  
34 in the art.

35 This ITO layer was then patterned into 256  
36 address lines using a 2 Watt CW (continuous wave) argon  
37 ion laser tuned to a wavelength of 514.5 nanometres.  
38 The EL laminate was mounted on a moveable X coordinate  
39 table, which moved the laminate in a direction

1 perpendicular to the lines being scribed beneath the  
2 laser beam. The laser beam was moved in the Y direction  
3 to scribe the lines. The laser beam was focussed to a  
4 12 micrometer spot and the laser power was adjusted so  
5 that the indium tin oxide, the underlying phosphor layer  
6 and about 10% of the combined underlying dielectric  
7 layers were ablated away where the laser beam had  
8 scanned (about 1.8 W). The scanning speed was  
9 controlled at about 100 and 500 mm/sec to provide  
10 address lines with about 40 or 25 micrometres gap  
11 respectively and address line depth of 6-8 or 3-4  
12 micrometres respectively. The spacing between address  
13 lines (i.e. between centres of the lines) was about 500  
14 micrometers. A vacuum adjacent the substrate withdrew  
15 vaporized and ablated material. The pattern of the  
16 transparent electrodes, once the ablation was completed,  
17 was as shown in Figure 9. On the completed display,  
18 there were about 50 column address lines per inch and a  
19 total of 256 columns.

20 Prior to scribing the ITO column address  
21 lines, the silver interconnects between the front  
22 (column) connector pads and the ultimate ITO address  
23 lines were screen printed from silver through a shadow  
24 mask in the pattern of Figure 10.

25 After laser scribing, the front viewing side  
26 of the completed display was sprayed with a protective  
27 polymer coating (Silicone Resin Clear Lacquer, cat #419  
28 from MG Chemicals).

29 The display was then tested by applying a  
30 voltage across selected pixels by connecting a pulsed  
31 power supply providing voltage pulses of 160 volts at a  
32 repetition rate of 64 Hz. The pixels each lit up  
33 reliably with a luminosity similar to that of the single  
34 pixel device of the previous example.

35 The resolution of the address lines of this  
36 example is generally much higher than is achievable with  
37 state of the art photolithographic techniques.

1           Commercially available devices typically have ITO  
2           address lines with widths of 180 - 205 micrometers and  
3           gaps between the lines of 65 - 80 micrometers. As set  
4           out above, in accordance with this invention, gaps of 25  
5           and 40 micrometers were produced, depending on the laser  
6           scanning speed. This higher resolution allows for a  
7           higher ratio of active to total area of the display,  
8           since wider ITO address lines with smaller gaps can be  
9           used.

#### 10           EXAMPLE 7

11                   This example illustrates a two layer  
12           dielectric constructed in accordance with the present  
13           invention but with the first dielectric layer being  
14           constructed from a paste having a higher dielectric  
15           constant than the paste used in Examples 3 and 4.

16                   The device was constructed as set forth in  
17           Example 3, but having a first dielectric layer formed  
18           from a lead niobate paste available from Electrosience  
19           Laboratories as a high K capacitor paste under the  
20           number 4210. The sintered paste has a dielectric  
21           constant of about 10,000. The first dielectric layer  
22           had a thickness of about 50 microns. A sol gel layer of  
23           PZT was applied, as described in Example 3, to a  
24           thickness of about 5 microns.

25                   The device functioned well with a threshold  
26           voltage for minimum luminance of 91 Volts and a  
27           luminosity at 150 Volts of 50 foot Lamberts.

#### 28           EXAMPLE 8

29                   This example illustrates a two layer  
30           dielectric constructed with a first dielectric layer  
31           formed from a lead niobate paste and a second dielectric  
32           layer formed from lead lanthanum zirconate titanate  
33           (PLZT). PLZT has a dielectric constant of about 1,000.  
34           The PLZT had a molar ratio of zirconium to titanium to  
35           lanthanum of 52:32:16.

1           The device was constructed as set forth in  
2       Example 3, with the sol gel layer being prepared as  
3       follows:

4           Into 50 ml of glacial acetic acid was  
5       dissolved 120 grams of 99.5% purity lead acetate. The  
6       resulting solution was heated to 90°C and held at this  
7       temperature for 2 minutes before being cooled to 70°C.  
8       Next, 55.4 grams of zirconium propoxide was added and  
9       the resulting solution was heated to 80°C and held at  
10      that temperature for 1 minute. After cooling to 70°C,  
11      21.8 grams of titanium isopropoxide was added. Next,  
12      11.4 grams of lanthanum nitrate was dissolved in 20 ml  
13      of glacial acetic acid, and this was added to the  
14      solution. Finally, to stabilize the solution and adjust  
15      the viscosity to a suitable value, 10 ml of ethylene  
16      glycol, 5 ml of propan-2-ol and 2.5 ml of demineralized  
17      water were added.

18           The PLZT sol gel was applied to the first  
19      dielectric layer by dipping in a manner similar to that  
20      described in Example 3. The dipped parts were fired at  
21      600°C to convert the second layer to PLZT. Four coats of  
22      PLZT were applied by successive dipping and firing in  
23      this way to prepare a surface of adequate smoothness for  
24      the deposition of the phosphor layer. A total thickness  
25      of 5 microns was achieved.

26           The device functioned well with a threshold  
27      voltage of 75 Volts and a luminosity of 37 foot Lamberts  
28      at 150 Volts.

29           All publications mentioned in this  
30      specification are indicative of the level of skill of  
31      those skilled in the art to which this invention  
32      pertains. All publications are herein incorporated by  
33      reference to the same extent as if each individual  
34      publication was specifically and individually indicated  
35      to be incorporated by reference.

36           The terms and expressions used in this  
37      specification are used as terms of description and not

1 of limitation. There is no intention, in using such  
2 terms and expressions, of excluding equivalents of the  
3 features shown and described, it being recognized that  
4 the scope of the invention is defined and limited only  
5 by the claims which follow.

## CLAIMS:

1. A dielectric layer in an electroluminescent laminate of the type including a phosphor layer sandwiched between a front and a rear electrode, the rear electrode being formed on a substrate and the phosphor layer being separated from the rear electrode by a dielectric layer, the dielectric layer comprising:

a planar layer formed from a ceramic material providing a dielectric strength greater than about  $1.0 \times 10^6$  V/m and a dielectric constant such that the ratio of the dielectric constant of the dielectric material to that of the phosphor is greater than about 50:1, the dielectric layer having a thickness such that the ratio of the thickness of the dielectric layer to that of the phosphor layer is in the range of about 20:1 to 500:1, and the dielectric layer having a surface adjacent the phosphor layer which is compatible with the phosphor layer and sufficiently smooth that the phosphor layer illuminates generally uniformly at a given excitation voltage.

2. The dielectric layer as set forth in claim 1, wherein the ratio of the dielectric constant of the dielectric material to that of the phosphor material is greater than about 100:1, and wherein the dielectric layer has a thickness such that the ratio of the thickness of the dielectric layer to that of the phosphor layer is in the range of about 40:1 to 300:1.

3. The dielectric layer as set forth in claim 1 in an electroluminescent laminate of the type including a thin film phosphor layer sandwiched between a front, transparent electrode and a rear electrode and separated from the rear electrode by the dielectric layer.

4. The dielectric layer as set forth in claim 3, having a dielectric constant greater than about

1 500 and a thickness in the range of about 10 - 300  
2 microns.

3 5. The dielectric layer as set forth in  
4 claim 4, formed from at least two layers, a first  
5 dielectric layer formed on the rear electrode and having  
6 the dielectric strength and dielectric constant values  
7 as set forth in claim 4, and a second dielectric layer  
8 formed on the first dielectric layer and having the  
9 surface adjacent the phosphor layer as set forth in  
10 claim 1, the first and second dielectric layers having  
11 a combined thickness as set forth in claim 4.

12 6. The dielectric layer as set forth in  
13 claim 5, wherein the first and second dielectric layers  
14 are formed from ferroelectric ceramic materials.

15 7. The dielectric layer as set forth in  
16 claim 5, wherein the second dielectric layer provides a  
17 dielectric constant of at least 20 and a thickness of at  
18 least about 2 microns.

19 8. The dielectric layer as set forth in  
20 claim 7, wherein the first dielectric layer provides a  
21 dielectric constant of at least 1000 and the second  
22 dielectric layer provides a dielectric constant of at  
23 least 100.

24 9. The dielectric layer as set forth in  
25 claim 8, wherein the first dielectric layer has a  
26 thickness in the range of about 20 -150 microns and the  
27 second dielectric layer has a thickness in the range of  
28 about 2 - 10 microns.

29 10. The dielectric layer as set forth in  
30 claim 9, wherein the first and second dielectric layers  
31 are formed from ferroelectric ceramic materials having  
32 perovskite crystal structures.

33 11. The dielectric layer as set forth in  
34 claim 5, 6 or 10, wherein the first dielectric layer is  
35 formed by thick film techniques followed by sintering at  
36 a temperature less than the melting point of the rear  
37 electrode.



1                   12. The dielectric layer as set forth in  
2 claim 11, wherein the first dielectric layer is formed  
3 by screen printing.

4                   13. The dielectric layer as set forth in  
5 claim 11, wherein the second dielectric layer is formed  
6 by sol gel techniques followed by sintering at a  
7 temperature less than the melting point of the rear  
8 electrode.

9                   14. The dielectric layer as set forth in  
10 claim 12, wherein the second dielectric layer is formed  
11 by sol gel techniques, including spin deposition or  
12 dipping followed by sintering at a temperature less than  
13 the melting point of the rear electrode.

14                  15. The dielectric layer as set forth in  
15 claim 5, 6, or 10, wherein the first dielectric layer is  
16 formed from lead niobate and wherein the second  
17 dielectric layer is formed from lead zirconate titanate  
18 or lead lanthanum zirconate titanate.

19                  16. The dielectric layer as set forth in  
20 claim 11, wherein the first dielectric layer is formed  
21 from lead niobate and wherein the second dielectric  
22 layer is formed from lead zirconate titanate or lead  
23 lanthanum zirconate titanate.

24                  17. The dielectric layer as set forth in  
25 claim 14, wherein the first dielectric layer is formed  
26 from lead niobate and wherein the second dielectric  
27 layer is formed from lead zirconate titanate or lead  
28 lanthanum zirconate titanate.

29                  18. The dielectric layer as set forth in  
30 claim 14 in a laminate having the rear electrode formed  
31 on a substrate which can withstand the sintering  
32 temperature.

33                  19. The dielectric layer as set forth in  
34 claim 18, wherein the substrate is alumina.

35                  20. The dielectric layer as set forth in  
36 claim 4, 5 or 14, wherein the surface of the dielectric  
37 layer adjacent the phosphor layer has a surface relief

1 which does not vary more than about 0.5 microns over  
2 about 1000 microns.

3 21. The dielectric layer as set forth in  
4 claim 17 in a laminate having the rear electrode formed  
5 of silver/platinum address lines on an alumina substrate  
6 and the front electrode formed of indium tin oxide  
7 address lines.

8 22. The dielectric layer as set forth in  
9 claim 21 in a laminate having a sealing layer above the  
10 front electrode.

11 23. A method of forming a dielectric layer in  
12 an electroluminescent laminate of the type including a  
13 phosphor layer sandwiched between a front and a rear  
14 electrode, the rear electrode being formed on a  
15 substrate and the phosphor layer being separated from  
16 the rear electrode by a dielectric layer, comprising:

17 depositing on the rear electrode, by  
18 thick film techniques followed by sintering, a ceramic  
19 material having a dielectric constant such that the  
20 ratio of the dielectric constant of the dielectric  
21 material to that of the phosphor material is greater  
22 than about 50:1, to form a dielectric layer having a  
23 dielectric strength greater than about  $1.0 \times 10^6$  V/m and  
24 a thickness such that the ratio of the thickness of the  
25 dielectric layer to that of the phosphor layer is in the  
26 range of about 20:1 to 500:1, the dielectric layer  
27 forming a surface adjacent the phosphor layer which is  
28 compatible with the electroluminescent layer and  
29 sufficiently smooth that the phosphor layer illuminates  
30 generally uniformly at a given excitation voltage.

31 24. The method as set forth in claim 23,  
32 wherein the ratio of the dielectric constant of the  
33 dielectric material to that of the phosphor material is  
34 greater than about 100:1, and wherein the ratio of the  
35 thickness of the dielectric layer to that of the  
36 phosphor layer is in the range of about 40:1 to 300:1.

1                   25. The method as set forth in claim 23,  
2 wherein the dielectric layer is formed in an  
3 electroluminescent laminate of the type including a thin  
4 film phosphor layer sandwiched between a front,  
5 transparent electrode and a rear electrode and separated  
6 from the rear electrode by the dielectric layer.

7                   26. The method as set forth in claim 25,  
8 wherein the dielectric constant of the ceramic material  
9 is greater than about 500 and the thickness of the  
10 dielectric layer is in the range of about 10 - 300  
11 microns.

12                   27. The method as set forth in claim 26,  
13 wherein the dielectric layer is formed as at least two  
14 layers, a first dielectric layer which is deposited on  
15 the rear electrode by thick film techniques and having  
16 the dielectric strength and dielectric constant values  
17 as set forth in claim 26, and a second dielectric layer  
18 which is deposited on the second dielectric layer to  
19 provide the surface adjacent the phosphor layer as set  
20 forth in claim 23, the first and second dielectric  
21 layers having a combined thickness as set forth in claim  
22 26.

23                   28. The method as set forth in claim 27,  
24 wherein the first and second dielectric layers are  
25 formed from ferroelectric ceramic materials.

26                   29. The method as set forth in claim 27,  
27 wherein the second dielectric layer provides a  
28 dielectric constant of at least 20 and a thickness of at  
29 least about 2 microns.

30                   30. The method as set forth in claim 29,  
31 wherein the first dielectric layer provides a dielectric  
32 constant of at least 1000 and the second dielectric  
33 layer provides a dielectric constant of at least 100.

34                   31. The dielectric layer as set forth in  
35 claim 30, wherein the first dielectric layer has a  
36 thickness in the range of about 20 -150 microns and the

1 second dielectric layer has a thickness in the range of  
2 about 2 - 10 microns.

3 32. The dielectric layer as set forth in  
4 claim 31, wherein the first and second dielectric layers  
5 are formed from ferroelectric ceramic materials having  
6 perovskite crystal structures.

7 33. The method as set forth in claim 27, 28  
8 or 32, wherein the first dielectric layer is deposited  
9 by thick film techniques followed by sintering at a  
10 temperature less than the melting point of the rear  
11 electrode.

12 34. The method as set forth in claim 33,  
13 wherein the first dielectric layer is deposited by  
14 screen printing.

15 35. The method as set forth in claim 33,  
16 wherein the second dielectric layer is deposited by sol  
17 gel techniques followed by sintering at a temperature  
18 less than the melting point of the rear electrode.

19 36. The method as set forth in claim 34,  
20 wherein the second dielectric layer is deposited by sol  
21 gel techniques, including spin deposition or dipping,  
22 followed by sintering at a temperature less than the  
23 melting point of the rear electrode.

24 37. The method as set forth in claim 27, 28,  
25 or 32, wherein the first dielectric layer is formed from  
26 lead niobate and wherein the second dielectric layer is  
27 formed from lead zirconate titanate or lead lanthanum  
28 zirconate titanate.

29 38. The method as set forth in claim 33,  
30 wherein the first dielectric layer is formed from lead  
31 niobate and wherein the second dielectric layer is  
32 formed from lead zirconate titanate or lead lanthanum  
33 zirconate titanate.

34 39. The method as set forth in claim 36,  
35 wherein the first dielectric layer is formed from lead  
36 niobate and wherein the second dielectric layer is

1           formed from lead zirconate titanate or lead lanthanum  
2           zirconate titanate.

3           40. The method as set forth in claim 36,  
4           wherein the dielectric layer is formed in a laminate  
5           having the rear electrode formed on a substrate which  
6           can withstand the sintering temperature.

7           41. The method as set forth in claim 40,  
8           wherein the substrate is alumina.

9           42. The method as set forth in claim 26, 27,  
10          or 36, wherein the surface of the dielectric layer  
11          adjacent the phosphor layer has a surface relief which  
12          does not vary more than about 0.5 microns over about  
13          1000 microns.

14          43. The method as set forth in claim 39,  
15          wherein the dielectric layer is formed in a laminate  
16          having the rear electrode formed of silver/platinum  
17          address lines on an alumina substrate and the front  
18          electrode formed of indium tin oxide address lines.

19          44. The method as set forth in claim 43,  
20          wherein the dielectric layer is formed in a laminate  
21          having a sealing layer above the front electrode.

22          45. An electroluminescent display panel  
23          providing for electrical connection from a planar  
24          electroluminescent laminate to voltage driving  
25          circuitry, comprising:

26                 a phosphor layer sandwiched between a  
27                 front and a rear set of intersecting address lines, the  
28                 rear address lines being formed on a substrate and the  
29                 phosphor layer being separated from the rear address  
30                 lines and optionally from the front address lines, by a  
31                 dielectric layer;

32                         said substrate forming a plurality of  
33                 through holes;

34                         means forming a conductive path through  
35                 each of the through holes in the substrate to each of  
36                 the address lines for providing for electrical

1 connection of each address line to the voltage driving  
2 circuit.

3 46. The display panel as set forth in claim  
4 45, wherein the voltage driving circuit includes voltage  
5 driver components, the outputs of which are connected to  
6 the address lines through the through holes, the voltage  
7 driver components being mounted on the rear of the  
8 substrate.

9 47. The display panel as set forth in claim  
10 46, wherein the means forming the conductive path  
11 comprises:

12 a conductive material deposited in each  
13 of the through holes forming front and rear connector  
14 pads on each side of the substrate; and

15 conductive material between the front  
16 connector pads and each of the address lines.

17 48. The display panel as set forth in Claim  
18 47, wherein the substrate is formed from a material  
19 which can withstand temperatures of about 850°C.

20 49. The display panel as set forth in Claim  
21 48, wherein the substrate is opaque.

22 50. The display panel as set forth in Claim  
23 48, wherein the substrate is alumina.

24 51. The display panel as set forth in claim  
25 47, wherein the substrate is generally rectangular and  
26 wherein the holes are formed around the perimeter of the  
27 substrate adjacent the ends of the address lines on at  
28 least two sides.

29 52. The display as set forth in claim 51,  
30 wherein the conductive material is a fired thick film  
31 paste.

32 53. The display as set forth in claim 52,  
33 wherein the conductive material to the rear address  
34 lines is silver/platinum and the conductive material to  
35 the front address lines is silver.

1                   54. The display as set forth in claim 46,  
2 wherein the means forming the conductive path through  
3 each of the through holes comprises:

4                   a first fired thick film conductive  
5 paste printed in a circuit pattern on the rear of the  
6 substrate and pulled through the holes in the substrate  
7 to provide front and rear connector pads, said rear  
8 connector pads providing for electrical connection to  
9 the voltage driving circuit; and

10                   a second fired conductive paste between  
11 the front connector pads and the address lines.

12                   55. The display as set forth in claim 54,  
13 wherein the voltage driving circuit includes voltage  
14 driving components and wherein the circuit pattern  
15 provides further connector pads for electrical  
16 connection for the outputs of the voltage driving  
17 components and to the drive circuit.

18                   56. The display as set forth in claim 55,  
19 wherein the substrate is generally rectangular and  
20 wherein the holes are formed around the perimeter of the  
21 substrate adjacent the ends of the address lines on at  
22 least two sides.

23                   57. The display as set forth in claim 56,  
24 wherein the first thick film paste is a silver platinum  
25 paste and the second thick film paste is a silver paste.

26                   58. The display as set forth in claim 54,  
27 wherein the dielectric layer comprises:

28                   a planar layer formed from a ceramic  
29 material providing a dielectric strength greater than  
30 about  $1.0 \times 10^6$  V/m and a dielectric constant such that  
31 the ratio of the dielectric constant of the dielectric  
32 material to that of the phosphor is greater than about  
33 50:1, the dielectric layer having a thickness such that  
34 the ratio of the thickness of the dielectric layer to  
35 that of the phosphor layer is in the range of about 20:1  
36 to 500:1, and the dielectric layer having a surface  
37 adjacent the phosphor layer which is compatible with the

1 phosphor layer and sufficiently smooth that the phosphor  
2 layer illuminates generally uniformly at a given  
3 excitation voltage.

4 59. The display as set forth in claim 58,  
5 wherein the dielectric layer is formed from at least two  
6 layers, a first dielectric layer formed on the rear  
7 electrode and having a dielectric constant greater than  
8 about 500 and a thickness in the range of about 10 to  
9 300 microns, and a second dielectric layer formed on the  
10 first dielectric layer and having the surface adjacent  
11 the phosphor layer as set forth in claim 58, the first  
12 and second dielectric layers having a combined thickness  
13 of about 10 to 300 microns.

14 60. The display as set forth in claim 59,  
15 wherein the first and second dielectric layers are  
16 formed from ferroelectric ceramic materials having  
17 perovskite crystal structures, wherein the first  
18 dielectric layer provides a dielectric constant of at  
19 least 1000 and has a thickness of about 20 - 150  
20 microns, and wherein the second dielectric layer  
21 provides a dielectric constant of at least 100 and has  
22 a thickness of about 2 - 10 microns.

23 61. The display as set forth in claim 60,  
24 wherein the first dielectric layer is formed by screen  
25 printing and sintering a thick film dielectric paste and  
26 the second dielectric layer is formed by sol gel  
27 techniques followed by firing.

28 62. The display as set forth in claim 61,  
29 wherein the first dielectric layer is formed from lead  
30 niobate and wherein the second dielectric layer is  
31 formed from lead zirconate titanate or lead lanthanum  
32 zirconate titanate.

33 63. A process for laser scribing a pattern in  
34 a planar laminate having at least one overlying layer  
35 and at least one underlying layer, comprising:

36 applying a focussed laser beam on the  
37 overlying layer side of the laminate, said laser beam



1 having a wavelength which is substantially unabsorbed by  
 2 the overlying layer but which is absorbed by the  
 3 underlying layer, such that at least a portion of the  
 4 underlying layer is directly ablated and the overlying  
 5 layer is indirectly ablated throughout its thickness.

6 64. The process of claim 63, wherein the  
 7 overlying layer is transparent to visible light and the  
 8 underlying layer is opaque to visible light and wherein  
 9 the wavelength of the laser beam is in the visible or  
 10 infrared region of the electromagnetic spectrum.

11 65. The process of claim 63, wherein the  
 12 composition and thicknesses of the layers are such that:

13  $\sum_i \alpha_u T_u > \sum_i \alpha_o T_o$   
 14 wherein;

15  $\alpha_u$  = absorption coefficient of underlying layer;  
 16  $\alpha_o$  = absorption coefficient of overlying layer;  
 17  $T_u$  = thickness of underlying layer; and  
 18  $T_o$  = thickness of overlying layer.

19 66. The process of claim 65, wherein the  
 20 composition of the layers is such that the overlying  
 21 layer vaporizes at a lower temperature than does the  
 22 underlying layer.  
 23

24 67. The process of claim 66, wherein the  
 25 composition of the layers is such that the overlying  
 26 layer has a higher thermal conductivity than does the  
 27 underlying layer.

28 68. The process of claim 63, wherein the  
 29 overlying layer is a transparent conductive material  
 30 into which an electrode pattern is scribed.

31 69. The process of claim 68, wherein the  
 32 electrode pattern is formed by moving one or both of the  
 33 laminate and the laser beam relative to the other.

34 70. The process of claim 69, wherein the  
 35 laminate is an EL laminate having overlying layers of a  
 36 transparent conductive material and phosphor and an  
 37 underlying layer of one or more dielectric layers and  
 38 wherein the electrode pattern consists of a plurality of

1 parallel spaced address lines of the transparent  
2 conductive material.

3 71. The process of claim 70, wherein a  
4 portion of the dielectric layer is directly ablated and  
5 the phosphor and transparent conductive material are  
6 indirectly ablated throughout their thicknesses.

7 72. The process of claim 71, wherein the  
8 transparent conductive material is indium tin oxide.

9 73. The process of claim 72, wherein the  
10 dielectric layer comprises:

11 a planar layer formed from a ceramic  
12 material providing a dielectric strength greater than  
13 about  $1.0 \times 10^6$  V/m and a dielectric constant such that  
14 the ratio of the dielectric constant of the dielectric  
15 material to that of the phosphor is greater than about  
16 50:1, the dielectric layer having a thickness such that  
17 the ratio of the thickness of the dielectric layer to  
18 that of the phosphor layer is in the range of about 20:1  
19 to 500:1, and the dielectric layer having a surface  
20 adjacent the phosphor layer which is compatible with the  
21 phosphor layer and sufficiently smooth that the phosphor  
22 layer illuminates generally uniformly at a given  
23 excitation voltage.

24 74. The process as set forth in claim 73,  
25 wherein the dielectric layer is formed from at least two  
26 layers, a first dielectric layer formed on the rear  
27 electrode and having a dielectric constant greater than  
28 about 500 and a thickness in the range of about 10 to  
29 300 microns, and a second dielectric layer formed on the  
30 first dielectric layer and having the surface adjacent  
31 the phosphor layer as set forth in claim 73, the first  
32 and second dielectric layers having a combined thickness  
33 of about 10 to 300 microns.

34 75. The process as set forth in claim 74,  
35 wherein the first and second dielectric layers are  
36 formed from ferroelectric ceramic materials having  
37 perovskite crystal structures, wherein the first

1 dielectric layer provides a dielectric constant of at  
2 least 1000 and has a thickness of about 20 - 150  
3 microns, and wherein the second dielectric layer  
4 provides a dielectric constant of at least 100 and has  
5 a thickness of about 2 - 10 microns.

6 76. The process as set forth in claim 75,  
7 wherein the first dielectric layer is formed by screen  
8 printing and sintering a thick film dielectric paste and  
9 the second dielectric layer is formed by sol gel  
10 techniques followed by firing.

11 77. The process as set forth in claim 76,  
12 wherein the first dielectric layer is formed from lead  
13 niobate and wherein the second dielectric layer is  
14 formed from lead zirconate titanate or lead lanthanum  
15 zirconate titanate.

16 78. A process of forming an EL laminate  
17 having a phosphor layer sandwiched between a front and  
18 rear set of intersecting address lines, the rear address  
19 lines being formed on a substrate and the phosphor layer  
20 being separated from the rear address lines, and  
21 optionally from the front address lines, by a dielectric  
22 layer, comprising the steps of:

23 (a) forming the rear address lines on the  
24 substrate;

25 (b) forming the dielectric layer on the rear  
26 address lines;

27 (c) forming the phosphor layer on the  
28 dielectric layer;

29 (d) optionally forming a transparent  
30 dielectric layer on the phosphor layer; and then

31 (e) forming the front address lines on the  
32 underlying phosphor or transparent dielectric layer by  
33 depositing a layer of transparent conductive material on  
34 the underlying layer and scribing the address lines  
35 therein with a focused laser beam, said laser beam  
36 having a wavelength which is substantially unabsorbed by  
37 the transparent conductive material, the transparent

1 dielectric layer and the phosphor layer but which is  
 2 absorbed by the underlying dielectric layer, such that  
 3 a portion of the underlying dielectric layer is directly  
 4 ablated by the laser beam and the overlying phosphor,  
 5 optional transparent dielectric and transparent  
 6 conductive material are indirectly ablated throughout  
 7 their thicknesses.

8 79. The process of claim 78, wherein the  
 9 laser beam has a wavelength greater than about 400 nm.

10 80. The process of claim 79, wherein the  
 11 composition and thicknesses of the layers are such that:

$$\sum_i \alpha_d T_d > \sum_i \alpha_t T_t ;$$

12 wherein:  
 13

14  $\alpha_d$  = absorption coefficient of underlying dielectric  
 15 layer

16  $\alpha_t$  = absorption coefficient of transparent layers

17  $T_d$  = thickness of underlying dielectric layer

18  $T_t$  = thickness of transparent layers.  
 19

20 81. The process of claim 80, wherein the  
 21 transparent conductive material is indium tin oxide.

22 82. The process of claim 81, wherein the  
 23 dielectric layer underlying the phosphor layer  
 24 comprises:

25 a planar layer formed from a ceramic  
 26 material providing a dielectric strength greater than  
 27 about  $1.0 \times 10^6$  V/m and a dielectric constant such that  
 28 the ratio of the dielectric constant of the dielectric  
 29 material to that of the phosphor is greater than about  
 30 50:1, the dielectric layer having a thickness such that  
 31 the ratio of the thickness of the dielectric layer to  
 32 that of the phosphor layer is in the range of about 20:1  
 33 to 500:1, and the dielectric layer having a surface  
 34 adjacent the phosphor layer which is compatible with the  
 35 phosphor layer and sufficiently smooth that the phosphor  
 36 layer illuminates generally uniformly at a given  
 37 excitation voltage.

38 83. The process as set forth in claim 82,  
 39 wherein the dielectric layer is formed from at least two

1 layers, a first dielectric layer formed on the rear  
2 electrode and having a dielectric constant greater than  
3 about 500 and a thickness in the range of about 10 to  
4 300 microns, and a second dielectric layer formed on the  
5 first dielectric layer and having the surface adjacent  
6 the phosphor layer as set forth in claim 82, the first  
7 and second dielectric layers having a combined thickness  
8 of about 10 to 300 microns.

9 84. The process as set forth in claim 83,  
10 wherein the first and second dielectric layers are  
11 formed from ferroelectric ceramic materials having  
12 perovskite crystal structures, wherein the first  
13 dielectric layer provides a dielectric constant of at  
14 least 1000 and has a thickness of about 20 - 150  
15 microns, and wherein the second dielectric layer  
16 provides a dielectric constant of at least 100 and has  
17 a thickness of about 2 - 10 microns.

18 85. The process as set forth in claim 84,  
19 wherein the first dielectric layer is formed by screen  
20 printing and sintering a thick film dielectric paste and  
21 the second dielectric layer is formed by sol gel  
22 techniques followed by firing.

23 86. The process as set forth in claim 85,  
24 wherein the first dielectric layer is formed from lead  
25 niobate and wherein the second dielectric layer is  
26 formed from lead zirconate titanate or lead lanthanum  
27 zirconate titanate.

28 87. An EL laminate comprising:  
29 a rear substrate;  
30 a rear set of parallel spaced address lines on  
31 the rear substrate;  
32 a dielectric layer on the rear address lines;  
33 a phosphor layer on the dielectric layer;  
34 an optional transparent dielectric layer on  
35 the phosphor layer;  
36 a front, transparent set of parallel spaced  
37 address lines above the phosphor layer, said front

1 address lines intersecting the rear address lines so as  
2 to form pixels at the intersections, said front address  
3 lines being separated by laser scribed grooves extending  
4 through the underlying phosphor layer and into, but not  
5 through, the underlying dielectric layer.

6 88. The EL laminate as set forth in claim 87,  
7 wherein the dielectric layer on the rear address lines  
8 comprises:

9 a planar layer formed from a ceramic  
10 material providing a dielectric strength greater than  
11 about  $1.0 \times 10^6$  V/m and a dielectric constant such that  
12 the ratio of the dielectric constant of the dielectric  
13 material to that of the phosphor is greater than about  
14 50:1, the dielectric layer having a thickness such that  
15 the ratio of the thickness of the dielectric layer to  
16 that of the phosphor layer is in the range of about 20:1  
17 to 500:1, and the dielectric layer having a surface  
18 adjacent the phosphor layer which is compatible with the  
19 phosphor layer and sufficiently smooth that the phosphor  
20 layer illuminates generally uniformly at a given  
21 excitation voltage.

22 89. The laminate as set forth in claim 88,  
23 wherein the dielectric layer is formed from at least two  
24 layers, a first dielectric layer formed on the rear  
25 electrode and having a dielectric constant greater than  
26 about 500 and a thickness in the range of about 10 to  
27 300 microns, and a second dielectric layer formed on the  
28 first dielectric layer and having the surface adjacent  
29 the phosphor layer as set forth in claim 88, the first  
30 and second dielectric layers having a combined thickness  
31 of about 10 to 300 microns.

32 90. The laminate as set forth in claim 89,  
33 wherein the first and second dielectric layers are  
34 formed from ferroelectric ceramic materials having  
35 perovskite crystal structures, wherein the first  
36 dielectric layer provides a dielectric constant of at  
37 least 1000 and has a thickness of about 20 - 150

1           microns, and wherein the second dielectric layer  
2           provides a dielectric constant of at least 100 and has  
3           a thickness of about 2 - 10 microns.

4           91. The laminate as set forth in claim 90,  
5           wherein the first dielectric layer is formed by screen  
6           printing and sintering a thick film dielectric paste and  
7           the second dielectric layer is formed by sol gel  
8           techniques followed by firing.

9           92. The laminate as set forth in claim 91,  
10          wherein the first dielectric layer is formed from lead  
11          niobate and wherein the second dielectric layer is  
12          formed from lead zirconate titanate or lead lanthanum  
13          zirconate titanate.

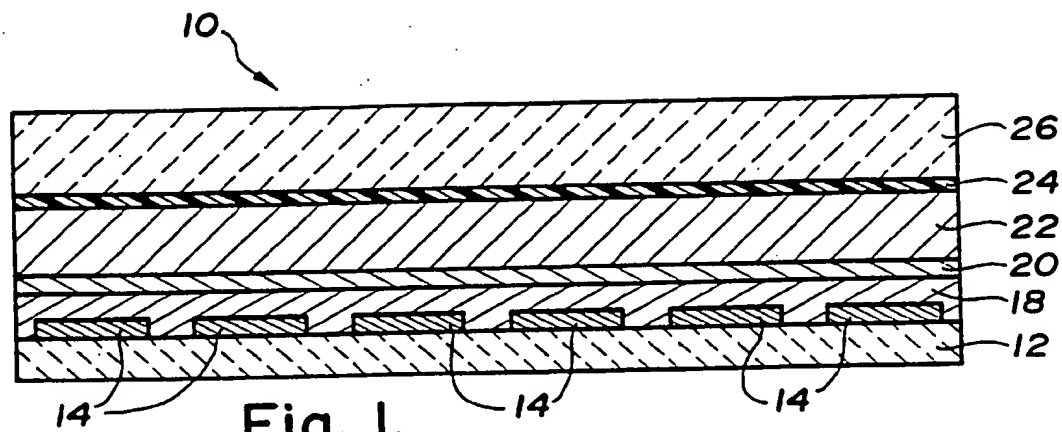


Fig. 1.

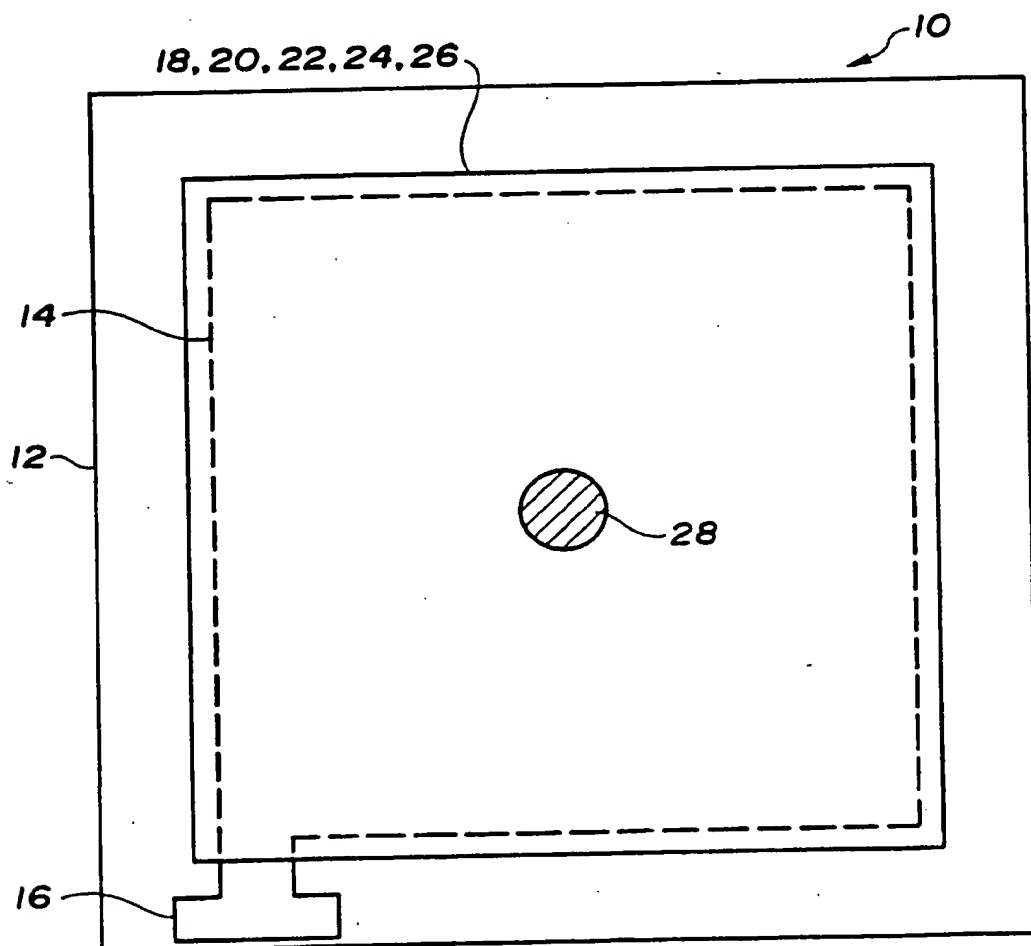


Fig. 2.



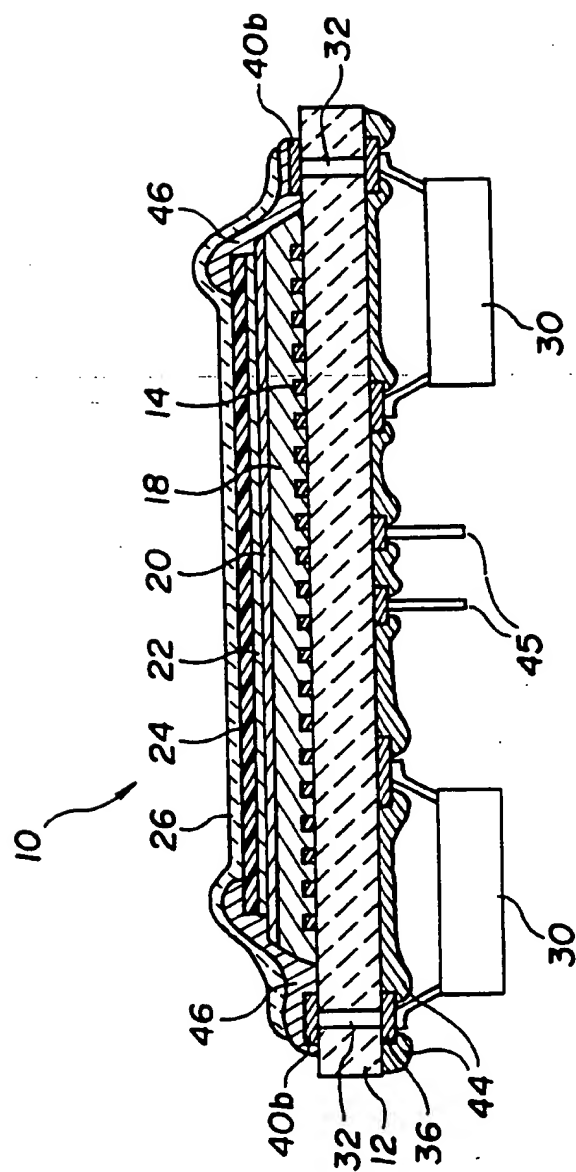


Fig. 3.

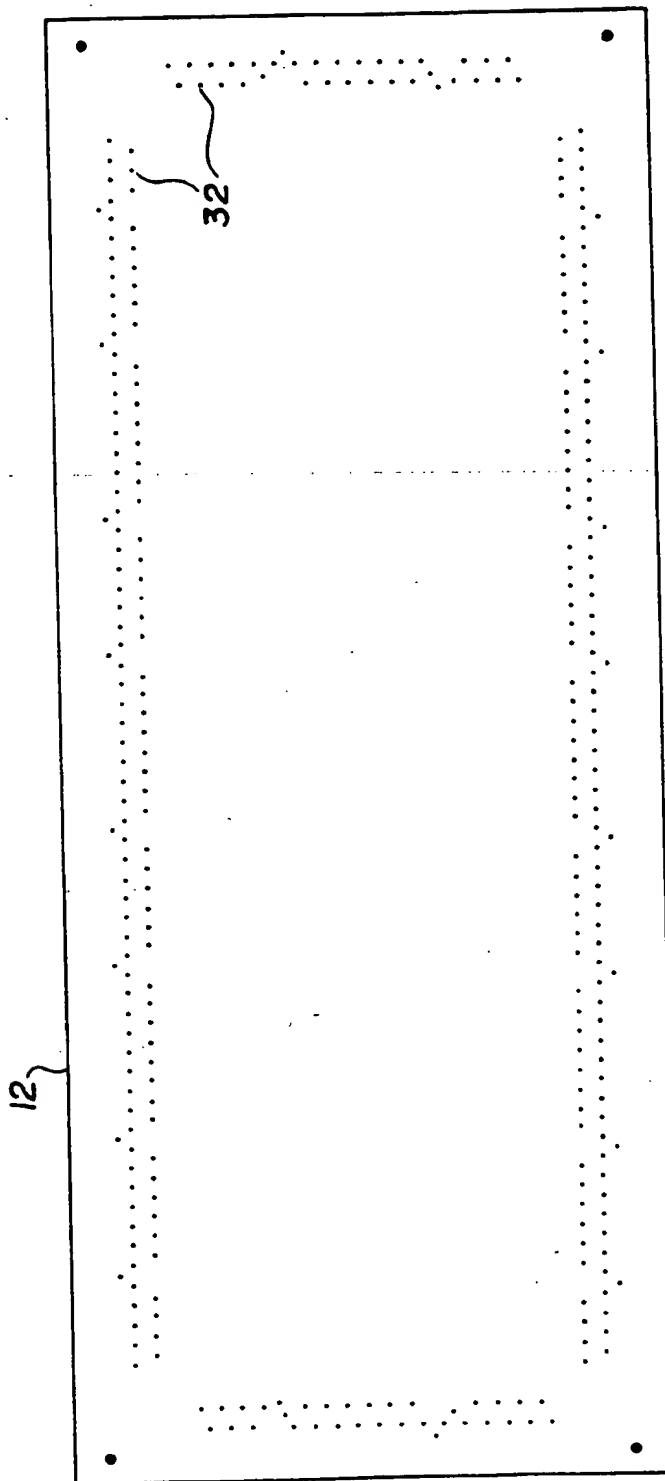


Fig. 4.

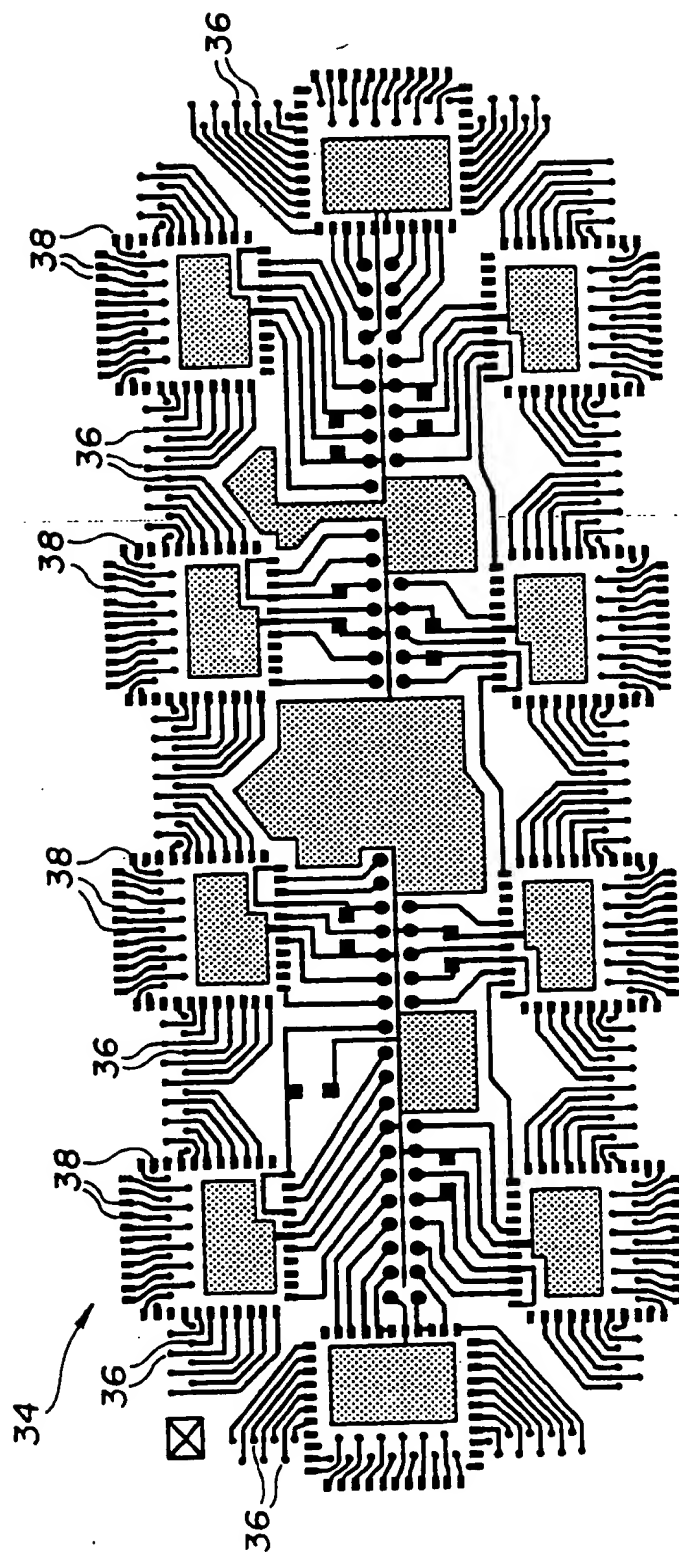


Fig. 5.

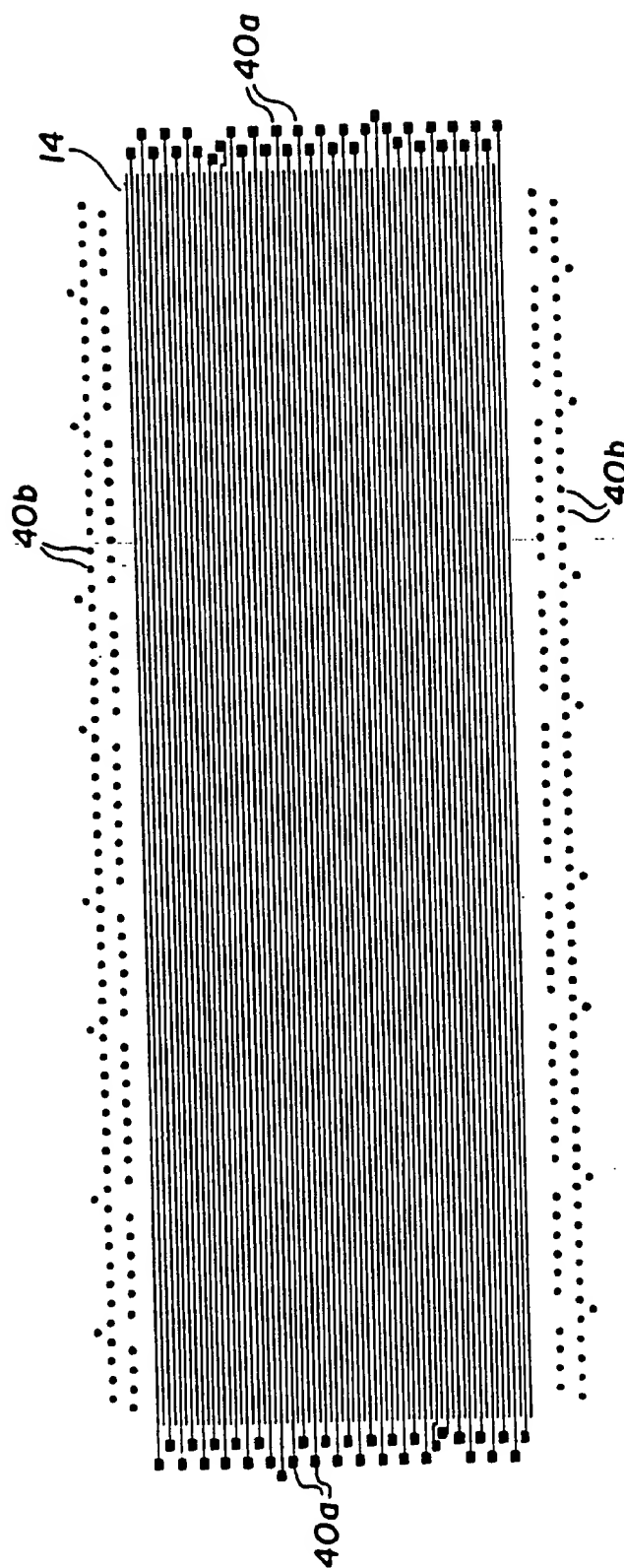


Fig. 6.

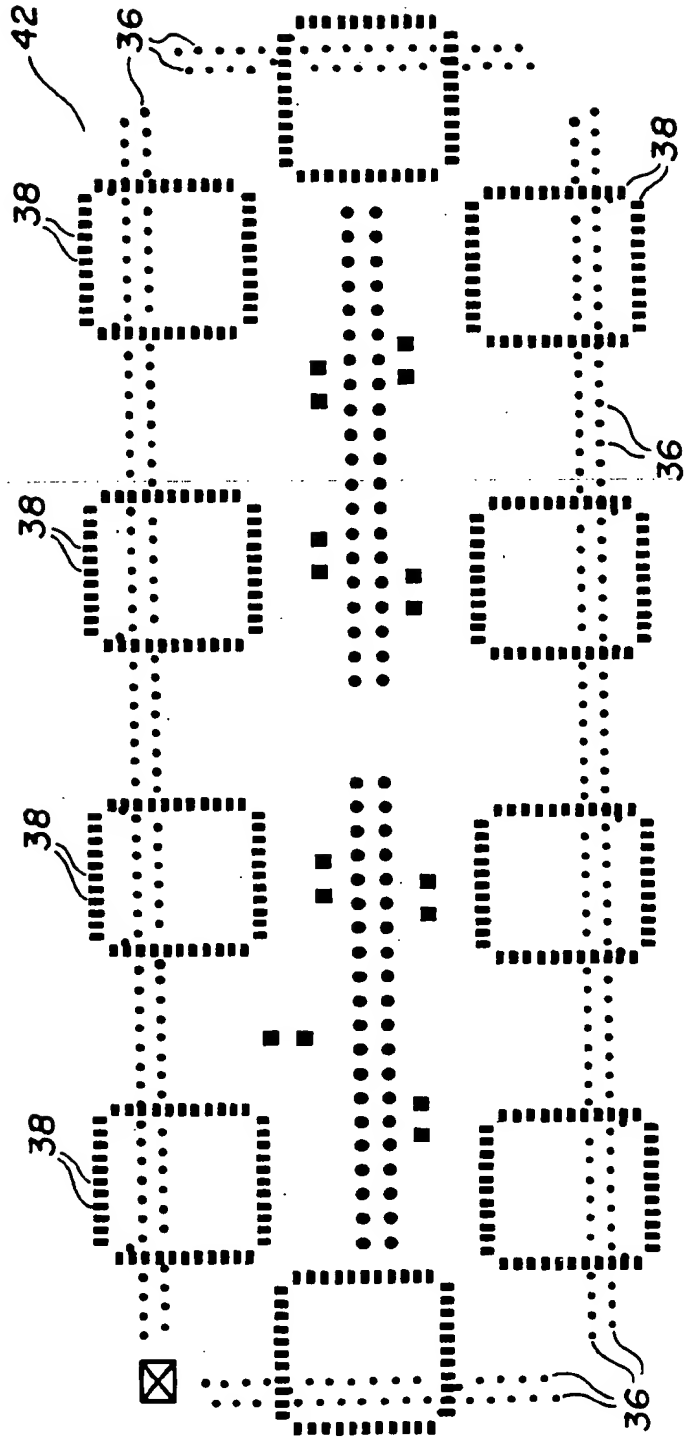


Fig. 7.

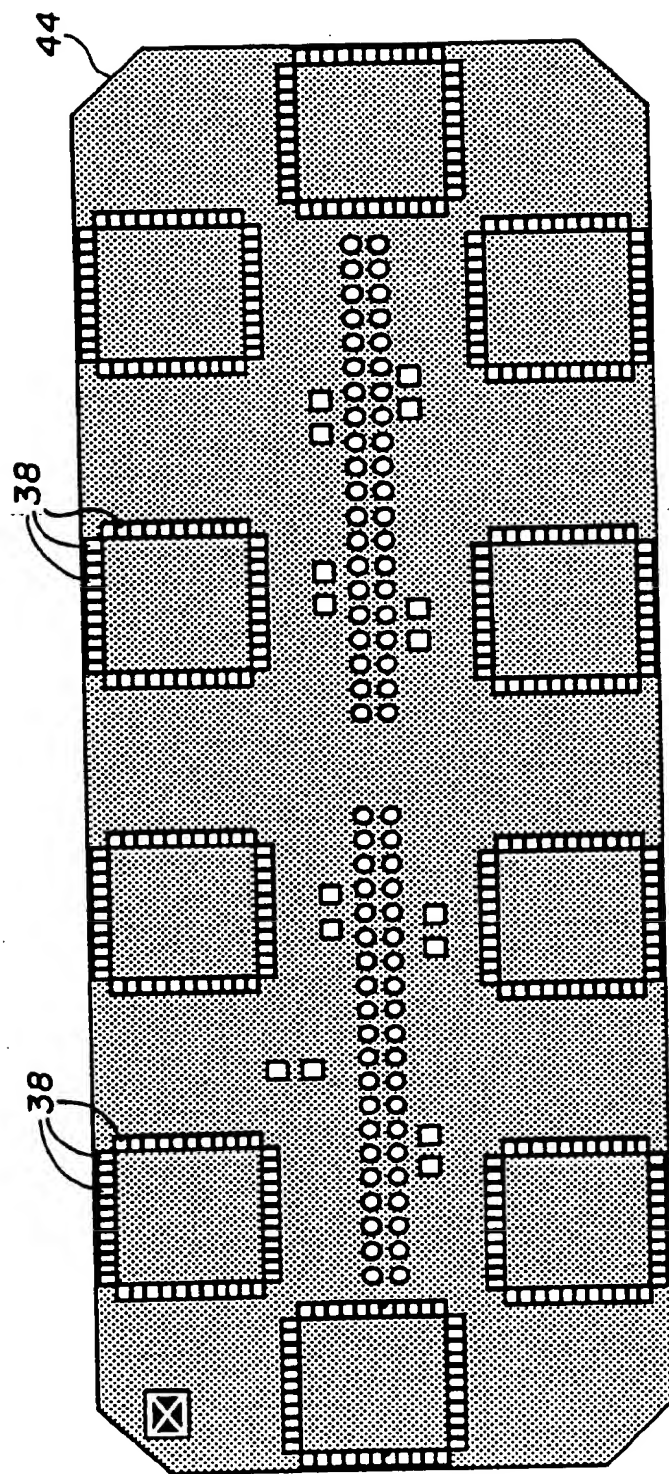


Fig. 8.

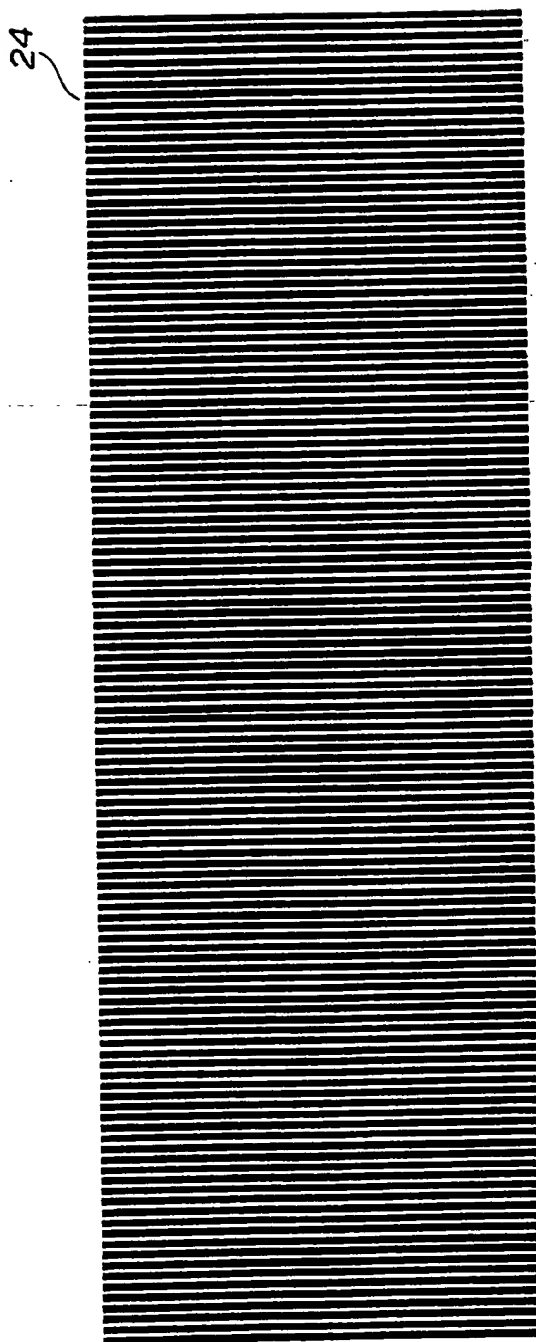


Fig. 9.

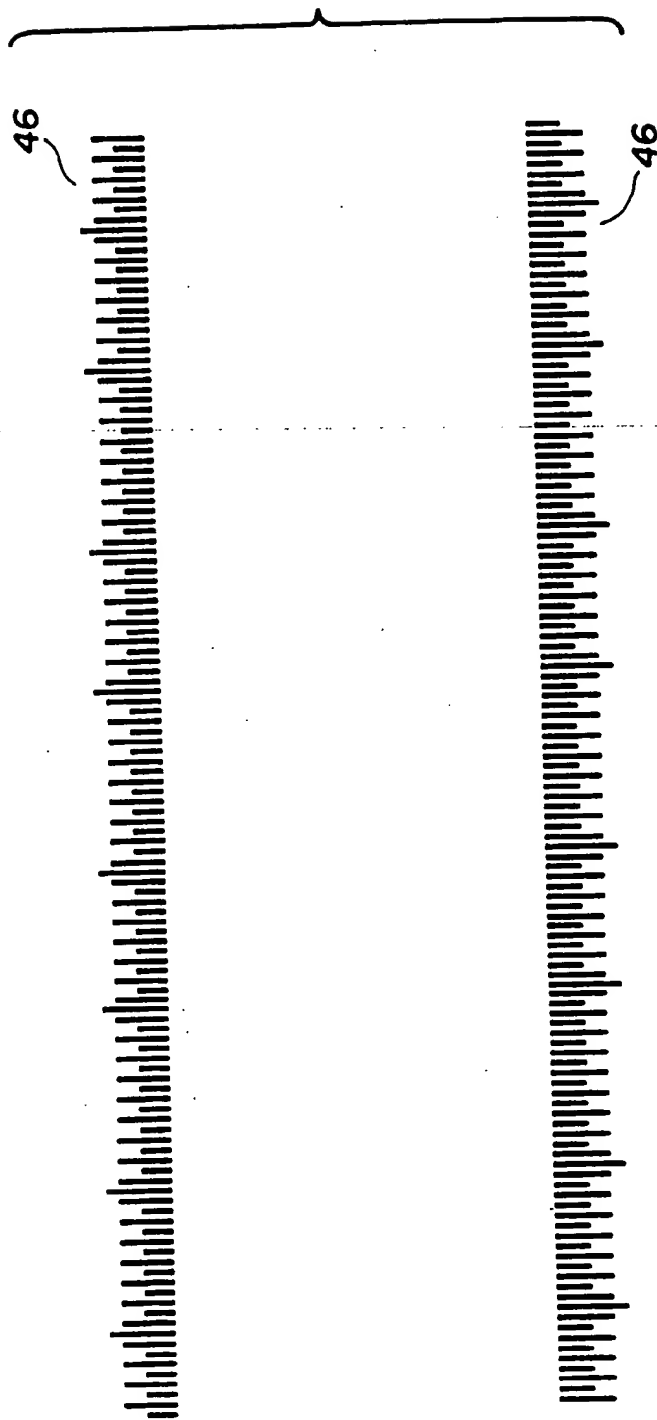


Fig. 10.



## INTERNATIONAL SEARCH REPORT

International Application No

PCT/CA 93/00195

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) <sup>6</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int.Cl. 5 H05B33/22;	H05B33/10;	H05B33/26; H05B33/12
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>7</sup>		
Classification System	Classification Symbols	
Int.Cl. 5	H05B	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup></b>		
Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
P,X	US,A,5 131 877 (T.MATHUMOTO) 21 July 1992 see the whole document ---	45-57
A	EP,A,0 145 470 (MATSUSHITA) 19 June 1985 see the whole document ---	1,3-7, 10,15
A	EP,A,0 111 568 (MATSUSHITA) 27 June 1984 see the whole document ---	1,3-7, 10,15
A	US,A,4 857 802 (M.FUYAMA & AL) 15 August 1989 cited in the application see the whole document ---	1-3,6,10
-/--		
<div style="display: flex; justify-content: space-between;"> <div> <p><sup>10</sup> Special categories of cited documents : <sup>10</sup></p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&amp;" document member of the same patent family</p> </div> </div>		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
06 AUGUST 1993	1 8. 08. 93	
International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE	DROUOT M.C.	

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 14, no. 205 (E-921)26 April 1990 & JP,A,20 44 691 ( MITSUBSHI ) 14 February 1990 see abstract ----	1,3-6, 11,45
A	PATENT ABSTRACTS OF JAPAN vol. 14, no. 38 (E-878)24 January 1990 & JP,A,12 72 095 ( UCHIJI MINAMI ) 31 October 1989 see abstract ----	1,5,6,9, 11
A	PROCEEDINGS OF THE SID vol. 28, no. 4, 1987, NEW YORK page 351-355 , XP7294 K.NUNOMURA 'TFEL CHARACTER MODULE USING A MULTILAYER CERAMIC SUBSTRATE' ----	1,3-11, 45-49
A	JAPANESE JOURNAL OF APPLIED PHYSICS vol. 28, no. 12, 1989, TOKYO pages 2446 - 2449 , XP100232 R.FUKAO & AL 'IMPROVEMENT OF LUMINOUS EFFICIENCY IN ZNS:TB,F THIN-FILM...' -----	1,3,10

# ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

CA 9300195  
SA 73360

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.  
The members are as contained in the European Patent Office EDP file on  
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information. 06/08/93

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A-5131877	21-07-92	None	
EP-A-0145470	19-06-85	JP-A- 60124396	03-07-85
		US-A- 4613546	23-09-86
EP-A-0111568	27-06-84	JP-B- 4039200	26-06-92
		JP-A- 58209093	05-12-83
		JP-B- 1018563	06-04-89
		JP-C- 1535981	21-12-89
		JP-A- 58212119	09-12-83
		WO-A- 8304339	08-12-83
		US-A- 4547703	15-10-85
US-A-4857802	15-08-89	JP-B- 5004797	20-01-93
		JP-A- 63184287	29-07-88